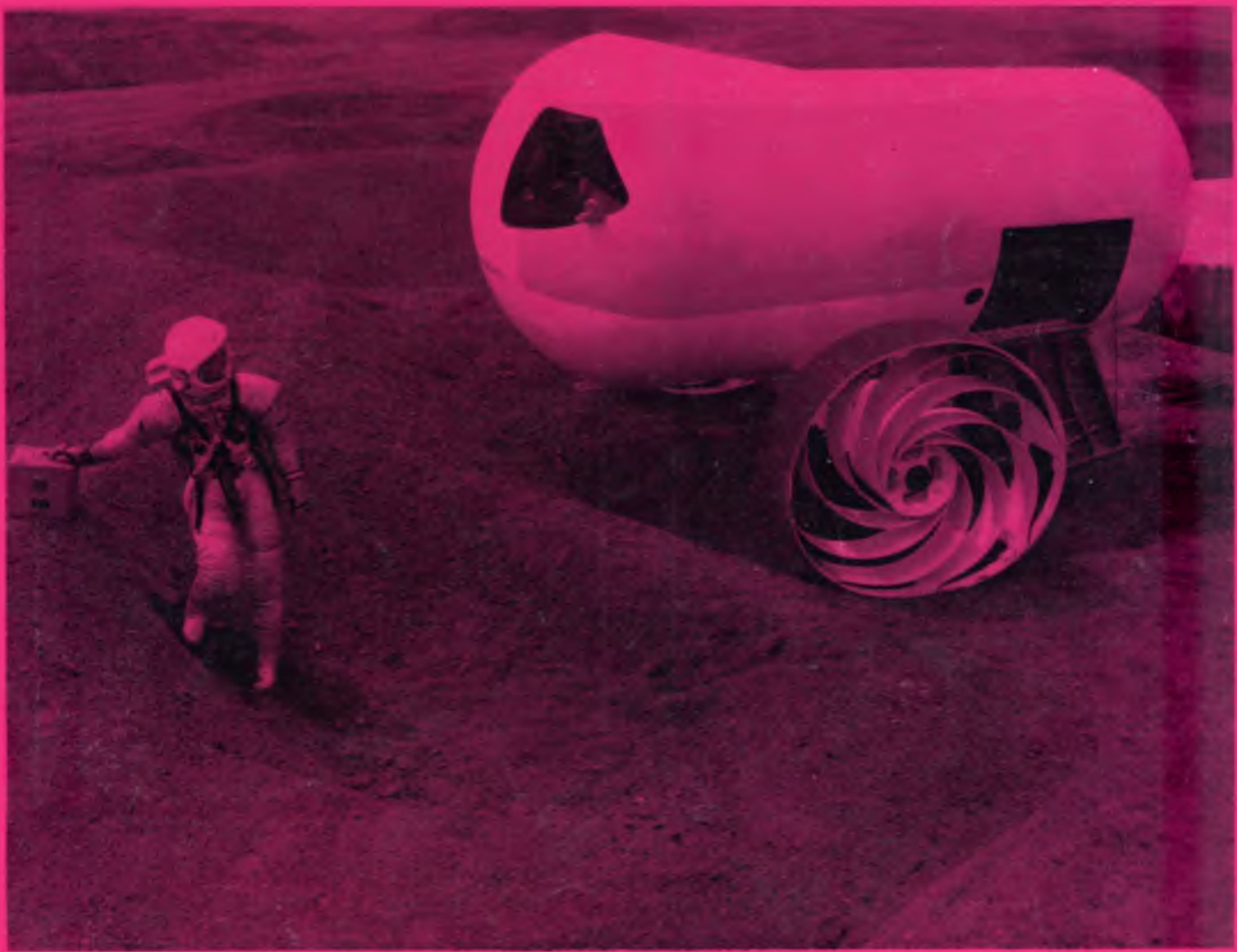
SPACEFLIGHT

Published by The British Interplanetary Society Volume 10 No 2 February 1968



JBIS

Journal of The British Interplanetary Society

Members will already know that the *Journal* will shortly be re-issued in a new and improved format, size 9¾ in. × 6¼ in. The first issue, i.e. Vol. 21 No. 1, will be published in March 1968. There will be four issues per year, averaging 96 pages per issue. Papers appearing in the first two issues are provisionally as follows:

Vol. 21 No. 1

Space Biology

Planetary and Space Environments	A. J. Meadows
Uniqueness of Biological Materials	A. E. Needham
Possible Forms of Life	A. Allison
Origin, evolution and diagenesis of Biogeochemical Matter	E. Degens
Evolutionary Biochemistry	M. H. Briggs
The Microbiology of Space	J. Hotchin
Sterilization and Decontamination techniques for Space Vehicles	C. W. Craven
Biosatellite Experiments	D. R. Ekberg
Biosatellite Project	P. M. Hahn

Vol. 21 No. 2

Problems and Development of Manned Flight in Space

Physiological Problems associated with acceleration in Space Flight	G. H. Glaister
Human Locomotion at Reduced Gravity	G. Cavagna
Lower body negative pressure	P. H. Fentem
Visual perception in simulated space conditions	J. A. M. Howe & R. L. Gregory
The Psychology of Space Flight and Centrifuge Training	R. M. Chambers
Isolation, Confinement and Sensory Deprivation	P. Suedfeld
The LIL Project of the International Academy of Astronautics	F. J. Malina
Orbital Space Stations	D. R. Ekberg
A proposed modular assembled antenna experiment for the SIVB	F. W. Forbes, R. P. Huie, S. D. Shook, J. E. Crawford, E. G. Blackwell and G. B. Reid

The subscription rate to libraries, other organisations, and to non-members of the Society is £4 4s. 0d. p.a., post free. The special inclusive reduced subscription rate to members is only one-half of this, i.e. £2 2s. 0d. p.a. Orders should be placed immediately with the Executive Secretary, British Interplanetary Society, 12, Bessborough Gardens, London, S.W.1.

Will you help us?

Personal recommendation is the cornerstone for the development of our Society. Our strength depends upon an active and influential membership. We need your help in all our endeavours. Here are some of the ways in which you can assist us.

* Discussing the Society's work with your colleagues and publicising our activities wherever possible.
* Submitting Articles and Features for publication in the *Journal* or *Spaceflight*.
* Contributing Book Reviews.
* Offering Lectures and Papers for Meetings.
* Undertaking Outside Lectures.

We need

* A larger Membership
* Advertising Support
* Additional Library Subscriptions

Put your ideas to us if you can assist in other ways

The Executive Secretary will always be pleased to help and advise.

British Interplanetary Society,

12, Bessborough Gardens, London, S.W.1

SPACEFLIGHT

Editor:
Kenneth W. Gatland

Reviews Editor:
L. J. Carter

Department Editors:
Dr. R. W. Maxwell
(Rocket Propulsion - Solid)
E. G. D. Andrews
(Rocket Propulsion - Liquid)
Dr. G. V. Groves
(Space Science)

A Publication of The British Interplanetary Society

Volume 10 No 2 February 1968

Milestones

Nov 22 First long-duration (123 sec) static test of Valois rocket engine of L.17 first stage of French Diamant B launch vehicle.

Nov 27 Soviet Union announces more tests of carrier rockets into two target areas of 80 n. miles diameter having co-ordinates of 32°15′N, 173°42′E, and 18°25′N, 178°30′W, between 28 November and 30 December. First impact area re-opened 13 December; second 15 December.

Nov 29 Australian WRESAT (Sparta) satellite launched from Woomera into 170–782 miles orbit, inclined at 83·35° to equator, to study influence of outer atmosphere on Earth's climate. Launch vehicle: modified Redstone of Sparta programme.

Dec 6 French Coralie stage fails to separate from HSD Blue Streak after successful launching of F.6/2 Europa test-vehicle at Woomera. Sequencer in Coralie "failed at lift-off."

Dec 13 US launches 143 lb Pioneer 8 spacecraft into solar orbit by Delta rocket from Cape Kennedy.

Dec 14 Surveyor 5 and Surveyor 6 re-activated on lunar surface by Earth command signals. The two craft, about 398 miles apart along the Moon's equator, "beamed radio signals at one another" to obtain a precise measurement of the Moon's libration. Surveyor 5 had been inactive since September; Surveyor 6 since 24 November.

Cover

Prototype of a lunar roving vehicle of the the type that may be transported to the Moon after the first manned landings. Called a Mobile Base Simulator, it has been under exhaustive test at Grumman's simulated lunar surface test site. The forward module would be pressurized to provide accommodation for two men, with full laboratory equipment. A full illustrated description of the vehicle appears on pages 42–43.
Grumman Aircraft Engineering Corporation.

Lunar Roving Vehicles

When man first arrives on the Moon his explorations will be limited to a comparatively small area around the landing craft. In order to visit areas of specific interest, large tracts of the lunar landscape will have to be traversed requiring the development of mobile laboratories. A number of schemes for lunar roving vehicles have been produced in recent years, the most definitive being performed by the Apollo Lunar Module prime contractor Grumman Aircraft Engineering Corporation. We are grateful to Grumman for the account that follows on Mobile and Fixed Base Lunar Simulators; also to P. J. Parker for details of other design concepts of lunar roving vehicles produced in the United States and the Soviet Union.

The prospect of landing men on the Moon in project Apollo has stimulated studies by the National Aeronautics and Space Administration and its industrial associates on the most feasible and economic methods of conducting lunar exploration. Among the possibilities for this post-Apollo lunar effort is a mobile laboratory which would extend the radius of exploration by astronauts otherwise limited to a walking investigation.

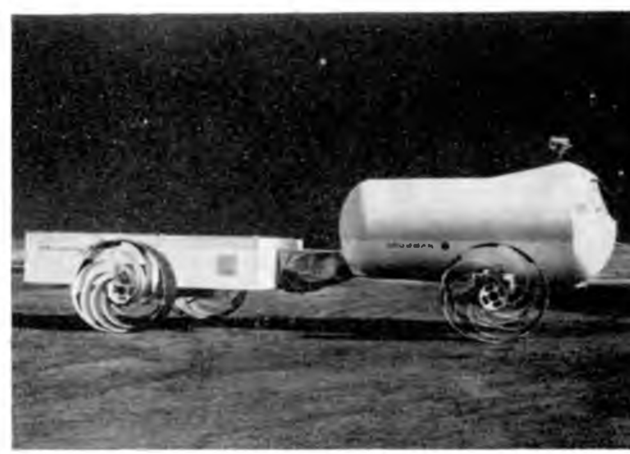
Until man arrives on the lunar surface, however, the detailed lunar surface characteristics will be subject to scientific conjecture. But from astronomical observation and information obtained by lunar probes such as the Ranger, Orbiter and Surveyor, the United States does have knowledge of gross surface characteristics, such as the size, shape and distribution of craters as well as photometric properties of the surface. The sizes and contours of some of these lunar surface features will require that the lunar vehicle be able to circumnavigate such obstacles to ensure a safe traverse. Therefore, the driver must be able to see the potential obstacles, estimate the required vehicle performance, and compare it to his vehicle's capabilities. This must be done in an environment where the driver has minimum visual cues and visual acuity is impaired by the variations in angle of incidence of the sunlight with respect to the surface.

During the past seven years many concepts of lunar roving vehicles have been studied by Grumman Aircraft Engineering Corporation. Since 1960, Grumman has also been actively engaged, using both Corporate funds and funding from NASA, in translating accumulated lunar data into lunar roving vehicle performance requirements and in learning how to compensate for the limitations imposed on the driver. To obtain maximum value from the available data, and to gain a technical insight into the problems of driving a vehicle on the Moon, Grumman has built with its own funds and is using two simulators, the Fixed Base, and the Mobile Base, to investigate the operational characteristics of the vehicle's driving controls and the driver's behavioural response. The resulting data on integrated man-vehicle performance characteristics are compared to predicted values to ascertain the validity of the empirical relationships used.

Mobile Base Simulator

The Mobile Base simulator (funded by Grumman) was designed and built as an Earth based prototype of a lunar roving vehicle of the type which could be transported to the Moon. Its function is to provide, by terrestrial testing, experimental verification of predicted vehicle performance on the Moon and the man-machine integration necessary for a successful lunar surface mobile mission.

The Mobile Base simulator is a two-module, four-wheeled vehicle with a wheel tread of 140 in. and an overall length of about 31 ft. The forward module is manned and capable of sustaining a pressure differential with respect to ambient.



Three views of the Mobile Base Simulator built by Grumman to study the problems of designing a pressurized vehicle for astronaut excursions on the Moon.
Grumman Aircraft Engineering Corporation

The aluminium pressure shell consists of a front end ellipsoidal dome, a tapered semi-monocoque transition section and a hemispherical rear dome. Its overall length, width and height are 14·5 ft, 9 ft and 7 ft respectively. The instrument panel, driving controls and two seats are located in the front end which has standing headroom. The forward dome (in front of the seats) has two windows that can be masked to smaller sizes to ascertain the effects on driving. The left rear side of the transition section has a large outward opening door which will be part of a two-man airlock in the vehicle. The manned module's interior has mockups of the environmental control system, communications system, work areas, bunks, etc. Telemetry equipment has been installed to transmit test data during the vehicle's operation at Grumman's simulated lunar surface test site.

The aft or unmanned module carries the primary power supply. It is rectangular, 13 ft long by 8·5 ft wide by 2·75 ft high, constructed from balsa cored aluminum sandwiched panels which are bonded to extruded joining members. Currently, the primary power supply consists of a gasoline engine driven generator located in the middle of the module. The engine also drives a hydraulic pump for steering and braking the Mobile Base simulator.

Each module is supported by two 5 ft diameter Metalastic wheels individually driven by reversible electric motors through a speed reduction unit located at the wheel hubs. Speed control is accomplished by varying the input voltage to the motors at each wheel. The Metalastic wheel is a patented Grumman proprietary development in which the metal spokes and rim are allowed to deflect such that the wheel under load has an equivalent diameter, at ground contact, three times larger than the constant diameter of the unloaded wheel. The larger "footprint" distributes the vehicle's weight over a larger area and allows it to traverse low bearing strength soils.

The manned and unmanned modules are coupled by an articulated joint which is used for steering the vehicle. This method of steering allows the driver to "slew" the forward module to the left or right to increase his peripheral field of view without any gross fore or aft motion. At present, an integrated controller is used for steering, braking and speed control. Separate forms of controllers can also be incorporated in the vehicle.

The manned and unmanned modules have identical suspension systems, the Metalastic wheel, suspension arm, a variable preload torsion bar spring and a shock absorber. Multi-module vehicle trains can be achieved by using articulated steering joints to connect additional powered-wheel modules to the existing ones.

The current series of Mobile Base simulator tests are being conducted at Grumman's simulated lunar surface test site. This consists of about two acres of ground contoured to match some of the Ranger photographs and is covered with cinders to approximate the Moon's photometric function.

The early test programmes were primarily concerned with obstacle recognition and avoidance, and the driving characteristics of the vehicle. Subsequently, the Mobile Base was controlled by space-suited drivers to check out the ease of control manipulation. More recent exercises have included a complete surface mission of vehicle checkout, foot sorties, sample gathering, extended periods of vehicle operation, delineation of daily routine procedures, and emergency operation of a damaged vehicle.

Fixed Base Simulator

The Fixed Base simulator (funded by Grumman) uses a moving belt, illumination system, TV camera and display screen, vehicle motion signal generator, lunar vehicle cockpit mockup and a computer to create the illusion of driving on the moon. The belt is 5 ft wide by 22 ft long and represents a lunar surface area of 125 ft by 550 ft. The belt is covered with a polyurethane foam whose colour and texture approximate the albedo and photometric function of the Moon's surface. The foam is sculptured to represent craters 5 to 20 ft in diameter with lips and centers as high or low as 2 ft. Parts of much larger craters and plateaus are also represented; distribution of obstacles is patterned after close-up Ranger photographs of the Moon. The belt runs over two drums driven by a servo motor at scale speeds up to 5 m.p.h. in forward or reverse as a function of the driver's throttle position.

Sunlight is simulated by using 1000 watt 3200°K lamps for creating collimated light. An array of eight of these is used to illuminate the simulated lunar surface at various incident angles.

The TV camera can rotate about an axis through the centre of its lens systems and also translate laterally across the width of the belt. The combined rotation and translation rates of the camera and the speed of the lunar surface are a direct function of throttle position and angle of turn made by the driver in the vehicle mockup. The camera image is projected on a screen in front of the mockup cockpit windows. As the driver manipulates the vehicle throttle and steering controller he sees the lunar surface moving in direct relation to his control of the vehicle.

A wheeled linkage, geometrically scaled to the dimensions of the Mobile Base simulator, is mounted to the front of the TV camera. The wheel supports are connected to linear potentiometers which provide varying signals as the wheels follow the contours of the lunar surface. These signals are received by a computer which is programmed with the lunar vehicle dynamic characteristics such as mass, moments of inertia, geometry of wheelbase and tread, suspension system stiffness and damping, etc. It computes the dynamic response of the lunar roving vehicle and sends corresponding control signals to a hydraulic system. This system actuates the mockup cockpit in roll and heave motions as though the mockup was actually a lunar vehicle traversing a part of the Moon's surface.

To simulate changes of the Sun's relative position, the collimated light array can be positioned to have the light impinge on the belt surface from different directions relative to the driver. The combination of a moving terrain under various lighting conditions and a mockup cockpit motion

Forward view from the Grumman Mobile Base Simulator. The vehicle has been driven on a simulated lunar surface in America prepared from information supplied by lunar probes.
Grumman Aircraft Engineering Corporation

corresponding to the terrain being traversed, allows a detailed study to be made of obstacle recognition and avoidance as a function of simulated environment and time to traverse a particular distance. Analogously, the cockpit and controls configurations, the desired type of driving feedback, and other vehicle design parameters, may be studied.

Alternative Designs

A number of other designs for lunar roving vehicles produced in the United States have concentrated on wheeled vehicles and personal propulsion devices, writes P. J. Parker. There have also been one or two conceptual ideas from the Soviet Union. Principal features are as follows:

GM MOLAB LRV (*U.S.A.*). The earliest of similar designs for MOLAB (Mobile Laboratory) was produced by General Motors Defense Research Laboratories. The General Motors proposal consisted of a six-wheeled vehicle with three flexibly-connected axles, the wheels being formed out of spring steel wires and covered with steel mesh. Maximum range of the vehicle was dependent upon surface conditions, maximum velocity being about 10 m.p.h. The vehicle, with a wheel diameter of 5 ft, would be able to climb a ridge of 10 ft high on the Moon.[1]

Boeing MOLAB LRV (*U.S.A.*). This MOLAB design by the Boeing Company was generally similar to the General Motors design, which was produced under sub-contract to Boeing. The Boeing MOLAB is 10 ft tall, 25 ft long and weighs more than 6000 lb. It consists of a four-wheeled cabin to which is joined, by a flexible metal frame, a two-wheeled rear unit. The vehicle has a ground clearance of 24 in. The six wheels are 5 ft in diameter and are individually-driven by their own electric motor powered by a hydrogen/oxygen fuel-cell system. Top speed is about 10 m.p.h. with a cruising speed around 5 m.p.h. The two-man crew would sit side-by-side in webbed seats suspended from the ceiling in the forward-end of the cabin unit. Besides a large forward viewing port the crew would be assisted by television cameras scanning the lunar surface, the images being transmitted to a television set located on the control console. The MOLAB provides oxygen, food and water for the crew, protects them from wide temperature extremes, high vacuum, penetrating radiation and meteoroid bombardment and allows lunar extra-vehicular activity by means of an air-lock. It could be used for a 14-day, 250 mile, lunar scouting trip.[1,2,3]

Bendix MOLAB LRVA (*U.S.A.*). This vehicle, also called MOLAB, is designed to provide living accommodation for two astronauts and to enable them to undertake lunar surface trips of up to 14 days, with a 7-day allowance for emergencies. The vehicle, which has four metal-elastic wheels, can carry 750 lb of scientific equipment with an operating range of 150 miles. Its missions could include deep drilling, selenological sampling, precise mapping and many other activities. A comfortable shirtsleeve environment with an oxygen atmosphere of 5 psia is provided. Water (obtained from the fuel-cell power system) and a small kitchen of dehydrated food are provided for the crew. An air-lock would allow lunar extra-vehicular activity.[1,4]

Northrop WBS LRV (*U.S.A.*). Called by its developers, Northrop Company, the Walking Beam Suspension (WBS) vehicle it is a 7000 lb two-man mobile laboratory capable of a two-week mission carrying, besides its two-man crew and associated equipment, about 600 lb of scientific equipment. It consists of a pressurized, cylindrical crew compartment resting on a support structure to which is attached the Walking Beam Suspension unit consisting of eight individually-powered wheels attached in pairs to individually-powered pivoted beams. The wheels can be raised and lowered and the beams rotated, locked or freed in any combination. By using this unique system the vehicle could climb-over obstacles more than 45 in high and cross crevasses over 80 in wide.

Top, electric powered "lunar jeep" developed by Boeing in co-operation with General Motors Defence Research Laboratory; woven-wire wheels provide good traction on loose soil as well as hard rock; *centre*, Bendix "molab" is tested on rough terrain at the Marshall Space Flight Center; wheels made of small circular springs absorb shocks encountered in transit over ridges and other obstacles; *bottom*, one-sixth scale model of Northrop "walking beam suspension" vehicle; wheels tend to follow surface contours while cabin remains approximately level.

The Boeing Company; Bendix Corporation and Northrop Nortronics

Top, the Bell Aerosystems Rocket Belt has propelled its operators over ground distances of 860 ft at speeds of 60 m.p.h. and to heights of more than 80 ft; *bottom*, a stand-up "pogo stick" which permits the operator merely to step aboard and fly away. Reduced gravity would make these devices five times more effective on the Moon.

Bell Aerosystems Company

Use of the 40-in diameter wheels with the Walking Beam Suspension arrangement provides a minimum ground clearance of 17 in with a maximum of 36 in. Top speed is 10 m.p.h. with a typical cruising speed of 2·5 m.p.h. and a mission range of about 250 miles. The vehicle utilises 'scuff-steering' techniques for directional control. ("Scuff-steering" is the application of different amounts of power to wheels on different sides of the vehicle in order to change the direction of the vehicle.) The vehicle is about 15 ft long, 12 ft high and 6 ft wide.[1,3,5]

Bell LRV's (*U.S.A.*). These are one-man lunar "flying vehicles" developed by the Bell Aerosystems Company. Several designs have been produced by this company including a "rocket belt," a "rocket flying chair" and a "rocket pogo stick"! The rocket belt, strapped on like a corset, on Earth propels the wearer at speeds of over 60 m.p.h. and a distance of about 860 ft. In the rocket flying chair concept the operator sits on a chair behind which is located the propulsion unit. Control handles extend from the propulsion unit, over the operator's shoulders, to his hands. The operator "flies" the machine by keeping upright in the chair and balancing it by varying thrust of the two propulsion jets. Directional control is obtained through movements of the arms and shoulders. The rocket pogo-stick is a stand-up version of the rocket chair. The two latter personal propulsion devices can carry, besides the pilot, about 150 lb of scientific equipment over distances of 12 miles.[6] Recently a two-man "pogo-stick" has been demonstrated.

Russian LRV 1 (*U.S.S.R.*). This unlikely concept was first seen in a Soviet documentary film on Russian cosmonauts and later re-printed in a French magazine.[7] It includes six legs, a rectangular body with a forward raised spherical cabin and large viewing ports, searchlights and communication antennae. The three-man vehicle, appears to be able to "walk" across the lunar surface by using its six pivoted legs to avoid large obstacles. Each leg can be moved individually. Two large protrusions on either side of the rectangular body may be some form of propulsion unit.

Russian LRV 2 (*U.S.S.R.*). This vehicle appeared in a line-drawing of a Soviet design for a manned underground lunar base in 1965. It appears to use tractor treads instead of wheels for traversing the lunar surface. It is about 15 ft long and 9 ft high and is reminiscent of snow-tractors of Antarctica.[8]

References

1. *Science Journal*, August 1966.
2. Boeing news release on MOLAB.
3. Private communication with G. Falworth, Astravista.
4. *Spaceflight*, March 1966, pp. 95.
5. Northrop news release.
6. *Science Horizons* USIS No. 76, November 1966, pp. 2–3.
7. *Paris Match*, 26 March 1966.
8. *Science Journal* May 1965, news item.

European Communications Satellites: A Special Issue

In view of the forthcoming European Space Conference in Bonn and the implications this may have for the future of European communications satellites and the ELDO-PAS launcher, we are devoting a major part of the March issue of *Spaceflight* to this vital topic. Contributions include: "Voices from the Sky" by Arthur C. Clarke, a former chairman of the B.I.S. who first proposed the geo-stationary communications satellite in May 1945; "Communications Satellites: The Eurospace Point of View" by G. K. C. Pardoe; "A Review of the Work of the Technical Planning Staff of the CETS" by Dr. N. Simmons; "The Position of CEPT on Telecommunications Satellites for Europe—Political and Economic Considerations" by F. Nicotera; and "Intelsat: Comsat's Point of View" by James McCormack.

Missiles from Space

By John W. Macvey

Next June a stray visitor from the asteroid belt is due to pass within four million miles of our planet—no great distance astronomically. This rock-like body, appropriately named Icarus, about half a mile across, is among the widest ranging of all the minor planets. When farthest from the Sun the planetoid travels beyond the orbit of Mars, whilst at perihelion it swings within only 19 million miles of the Sun.

An even closer approach was made by the minor planet Hermes discovered by Reinmuth 30 years ago. During the last days of October 1937 this object passed the Earth at a distance of just over 400 000 miles. Indeed it is believed that on occasion Hermes, 1 mile in diameter and with a mass of some 3 billion tons, can come within 220 000 miles of the Earth. This robs the Moon of the permanent distinction of being the nearest celestial body to the Earth. What are these objects that, big and small, approach our world and sometimes enter its atmosphere?

"Shooting Stars"

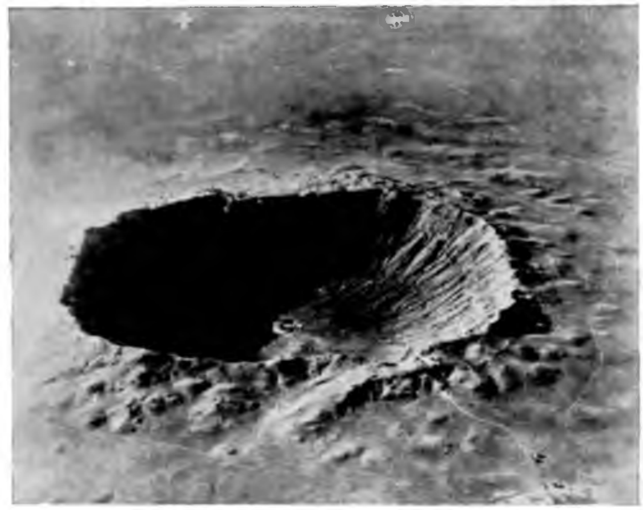
There is little that for sheer peace and tranquillity can equal the sky at night. Yet appearances can be deceptive. There must be few people today who are unacquainted with the "shooting star." Such objects of course are not stars at all but small particles of matter usually varying in size from specks of dust to pea-size lumps. They become transiently and often magnificently luminous as they rush through the Earth's atmosphere when friction heats them to incandescence. If any part of them reaches the Earth's surface at all it is in the form of the minutest particles. Space is full of these tiny objects; it is estimated that our planet sweeps them up at the rate of some 25 million per day.

What, however, it might be asked, is the position regarding really large meteorites, those large enough to remain partially unconsumed by friction and thus able to reach the surface of our planet. Do not such objects constitute a real menace? Such occurrences, were they frequent, would indeed be serious. Fortunately such cosmic missiles are very few and far between.

To what do meteorites owe their origin? They could be the débris of a larger planet (or planets) which aeons ago was violently shattered. The same origin may be attributed to the much smaller harmless particles. On the other hand such matter may simply represent the unused "raw material" of the Solar System. How many large meteorites have struck the Earth? The record is one which must, of necessity, be incomplete. In prehistoric times many of these enormous missiles from space may have collided cataclysmically with Earth. Over aeons of time, however, the effect of climatic erosion has mellowed and all but obliterated the evidence of their impact. There does exist, however, certain evidence of meteorites of vast dimension having impacted our world.

It is advisable at this point to distinguish between "meteors" and "meteorites." The former are very small and are totally consumed by atmospheric friction before they reach the Earth's surface. A normal faint meteor has a particle size of about 1 mm while a brighter specimen may have dimensions of the order of 1 cm. Larger ones, often termed "fireballs," may range from 1–10 cm. They begin to glow some 65 miles up and the lowest point of the trail they leave may be about 50 miles above the Earth. By then the meteor has been totally consumed by friction.

Meteorites on the other hand are meteors which manage to reach the ground before they are burned out. The majority possess a thin, darkish, vitreous crust. Chemically they vary greatly in composition, some consisting of iron and nickel while others are of stony origin in which silicates predominate.



The crater some 20 miles from Winslow in Arizona formed by a huge meteorite believed to have fallen in pre-historic times. It is approximately 4000 feet across and 600 ft deep; at the centre is a museum.

United States Information Service

The descent of a really large meteorite is a phenomenon unlikely to be forgotten. A vast, fiery mass appears suddenly in the sky behind which follows a long luminous trail. The incandescent nucleus then usually disintegrates with a loud explosion, whereupon dark fragments fall to the ground emitting as they do a reverberating or hissing sound.

The Barringer Meteorite

Probably the best known of all meteorite craters is the vast depression in Arizona some 20 miles to the south-west of Winslow. It measures 4000 ft across, is 600 ft deep and has sides rising 130 ft. This represents the evidence of the now legendary Barringer Meteorite which fell long before recorded history and in so doing displaced *millions* of tons of rock. The area known as Coone Butte, is only 70 miles or so from the famous Grand Canyon of Colorado and about 2½ miles from a region known as Canon Diablo, noted for its scattered meteorites. The crater itself lies in a large level plain of limestone and sandstone. It is a truly impressive sight. The meteorite itself is estimated to have weighed up to 10 million tons.

Precisely when it fell is difficult to estimate. Various suggestions have been advanced and these vary widely. A tree presently growing on the ridge of the enormous crater is apparently 700 years old but it seems more than likely that the impact occurred long before that. The extent to which the crater has been eroded leads geologists to believe that the object may have fallen as long as 50 000 years ago!

It is thought to have been an iron meteorite in view of certain geological features, *e.g.*, the crater-like depression, the presence of pulverized and partly molten sandstone conglomerated with a nickel-iron mixture inside the crater, the huge upward tilted rocks on the crater's rim and the many rock fragments lying outside. A large number of iron meteorites have also been found within several miles of the crater varying in size from small fragments to great blocks weighing hundreds of pounds.

The position of the main mass has long been a source of conjecture. The present belief is that it lies buried under the crater's southern rim. Certainly the asymmetry of the crater walls would seem to indicate that the object did not descend vertically but arrived from a northerly direction.

Borings have been carried out in this vicinity and at a depth of 1200 ft quantities of nickel and iron have been located. This may well represent the "top" of the great meteorite.

Geologists reckon that the amount of crushed, displaced rock amounts to about 350 million tons. If the object itself weighed around 10 million tons, 400 ft would have been the anticipated diameter of the crater, a mere third of its real diameter. The heat generated may have been in the region of 1400 to 1800° C. Examination of some of the ejected sandstone shows evidence of the force of impact. In places individual sand grains have been pulverized into a fine "silica meal." Table 1 gives the location of other large meteorite impacts.

TABLE 1.—*Some Large Meteorites*

Locale	Details
(1) West of Hanbury, Central Australia	Thirteen craters within an area of ½ sq. mile, largest about 200 yd wide. Crater walls largely eroded. Large quantities of nickel/iron fragments scattered over entire region, biggest weighing 290 lb[11]
(2) 50 miles south of MacDonnel Range	Three large craters 220 ft × 120 ft. Depth 50–60 ft. Over 1300 pieces of meteoric iron found, largest over 170 lb. Aborigines refuse to camp near spot which they have termed "chindu, chinna, waru chingi yabu" or "sun-walk, fire-devil rock."[12]
(3) Long Island, U.S.A.	Biggest known *stone* meteorite, broke on impact into four large and more than 3000 small fragments. Some smaller stones actually *seen* to fall.[11]
(4) Near Cape York, West Coast of Greenland	Four large iron meteorites, largest weighing 79 200 lb.[11]
(5) Knyahinya, Czechoslovakia	640 lb weight. Fell 9 June 1866. Penetrated to depth of 11 ft.[11,13]
(6) Hoba, S.W. Africa	60 tons in weight. Upper surface is level with surrounding terrain. No sign of crater around it.[13]
(7) Odessa, Texas, U.S.A.	Mass of meteoric iron fell here in 1921. Spot marked by a crater roughly circular with average diameter of 530 ft.[13]

The Tunguska Phenomenon

If the Barringer Meteorite fell in pre-historic times it has certainly a rival of much more recent vintage.[3] This of course is the famous Tunguska Meteorite which fell in central Siberia on 30 June 1908 (0^h, 17^m, 11^s UT). The area is some 500 miles to the north of Lake Baikal (60° 55′ N; 101° 57′ E). This part of the world was then less accessible than it is today and it was not until 1927 that an expedition organized by the U.S.S.R. Academy of Sciences reached the scene. Of that expedition and its findings more later.

At the time of the fall an express train was passing along the famous Trans-Siberian railway. Suddenly, as in some nightmare, the track ahead was seen to heave and buckle as if imbued with life. Fortunately the driver of the locomotive was able to bring the express to a halt within a few feet of the distorted metals though many passengers were hurled violently from their seats as a consequence—and all because some 400 miles distant a great chunk of matter had plunged into the Earth.

The passengers and crew of the Trans-Siberian Express were not alone in the knowledge that something extraordinary had happened, for the violence of the impact had caused seismic waves to be recorded at four observatories, the most distant being at Jena in central Germany. Barometric readings in England 5 hr later indicated some unusual and tremendous natural event. In addition there were peculiar effects in the sky which were discussed at a meeting of the British Astronomical Association in July that year. The remarkable red sunset glow was described by one observer in the following terms: "About 9.30 p.m. as seen from Greenwich the sunset did not differ much from that of a normal fine summer day except that the luminosity lay more to the north. By 1 a.m. it had shifted a little to the east being if anything more brilliant by now. The most remarkable feature was the intensity of the light over the whole northern sky which by then resembled the southern sky under the light of a full Moon."[2] This effect was in all probability due to dust raised by the object's fall and carried westward around the world. At 7 p.m. on 30 June, a Mr. de Veer of Haarlem, near Amsterdam, reported "an undulating mass to the north-west which was *not* cloud for the blue sky itself seemed to undulate.'[6]

The expedition of 1927, led by Academician Kulik, found that the devastation then, 19 years later, was still extensive. Trees had been blown down over a radius of 25 miles. Some in fact had been totally uprooted; their roots pointed toward the centre of the "explosion" like the spokes of a great wheel. Further expeditions in 1928 and 1929 revealed that the region had been severely ravaged by fire and that searing could be traced to a distance of 6–11 miles from the supposed impact centre. No great single crater was anywhere in evidence though numerous small depressions were found. Despite borings none yielded meteoric material.

Poignant, colourful descriptions of the event were made to Kulik by inhabitants of the region. One, Vassili Ilich, had a herd of 500 reindeer in the area of the object's descent. "The fire came by," he said, "and destroyed the forest, the reindeer and all other animals."[4] Shortly after the blast, the distorted and burned remains of a few reindeer had been discovered; of the rest there was no trace![4] A farmer named Semenov, at Vanovara[5] nearly 40 miles away, reported "an enormous fireball in the north and a fierce, terrible wave of heat which burned the shirt from my body." He was hurled a distance of several feet, his barn largely wrecked and every pane of glass in his house shattered. His fellow farmer and neighbour, one P. P. Kosolopov, said it was as if the ears were being burnt from his head. He sought refuge in his house which then more or less collapsed about him.[4] Another odd manifestation was the fact that Vassili Ilich's silverware and tin utensils melted, though some large buckets remained intact.[4] According to another witness the object was seen in a cloudless sky over an area nearly 1000 miles in diameter and was likened to the flight of a blindingly bright bolide "which made even the light of the Sun seem dark."[5]

Further references from countries other than England and Holland were made to the peculiarly bright nights which affected all Europe and West Siberia. Indeed as far south as the Caucasus it was possible to read a newspaper at midnight without the aid of artificial light. This peculiar luminescence disappeared gradually over the ensuing two months.[5]

The Observatory at Irkutsk, as well as others, reported a resultant and definite disturbance of the Earth's magnetic field and this was attributed to the Tunguska celestial visitor.[5]

According to Krinov, the dazzling "fireball" moved within the space of a few seconds from south-east to north-west leaving a trail of what he describes as "dust." Flames and a cloud of smoke were observed over the immediate area of the fall. Indeed spectacular visible phenomena were seen from as far away as 400–500 miles and loud explosions were heard afterwards at distances in excess of 600 miles.[7]

It was fortunate indeed that the body chose so sparsely a populated area for its descent. Had the "target area" been a large city the effects would have been devastating. If such a fall had occurred in the United States, say around Chicago, visible phenomena, it is reckoned, would have been noticed as far to the south-east as Pittsburgh, as far south as Nashville and as far west as Kansas City. Its dreadful thunder would have been heard in Washingon D.C., Atlanta, Tulsa and in the States of Oklahoma and North Dakota. Today such an event might well be misinterpreted as the arrival of a thermonuclear ICBM and so set loose the holocaust which could lead us directly back from space to stone age (or beyond!).

If the object was in fact a meteorite it may have belonged to the Pons-Winnecke Swarm. It could hardly, however, as was once suggested, have been part of the comet itself for by then this would have passed perihelion and been a long way from Earth.[6]

So far we have considered the object rather freely as a meteorite, but certainly it left no crater on the Arizona pattern.[8] To explain this anomaly it has been suggested that the meteorite utterly destroyed itself by the sheer violence of the explosion. The weakness here is the scarcity of meteoric dèbris and the lack of small to medium craters. Only a few scattered fragments were found and those depressions which do exist are of doubtful validity so far as meteoric origin is concerned. It was then suggested that the main large crater, created in a large area of frozen ground, had soon lost all definite form by virtue of such heat as the Siberian sun offers. However, it seems reasonable to believe some largish irregular depression would have remained.

In 1930, Astapovich and Whipple, working independently, came out strongly in favour of impact with a cometary head. Certainly there does exist some evidence in favour of such a concept.[9]

(1) Direction of the body's flight was opposite to that of Earth and the resultant high collision velocity (60 km/sec[5]) could have yielded the impact energy of approximately 10^{23} ergs.[5]

(2) Whipple postulated that the composition of a cometary nucleus or head is largely ice, CH_4, NH_3 and traces of mineral matter. Thus the absence of much solid material on the ground could be explained.

(3) The spectacular luminescence of the night sky immediately after the event. Though observed in Siberia, European Russia and western Europe, this was not observed either in the United States or the southern hemisphere.

The tail of a comet is always directed *away* from the Sun (a repulsion effect). Was the tail of this particular comet at the moment of impact streaming outward in a north-westerly direction? It was estimated in 1961 that dissipation of such a tail could have resulted in a night sky initially brighter by about 50–100 times though still possessing a brightness 10^4 less than that of daylight.[10] The seeming weakness underlying this argument is the apparent unlikelihood that a comet, even a small one, on a collision course with Earth, would have gone unobserved. But if the object were cometary it is interesting to dwell on the possible extent of the object. Fesenkov estimates a diameter of several hundred metres.[10]

Zolotov, on the other hand, has suggested that the energy expended as the object broke up was nuclear. His ideas are based on the following premises and observations.

At a distance of approximately 10–12 miles from the apparent epicentre, he found trees, subjected to thermal flash, which had started to burn. A forest fire of natural origin can be ruled out since a living tree requires 60–100 cal/cm^2 of incident thermal radiation to start ignition. Calculations put the radiant energy of the explosion as $1{\cdot}5 \times 10^{23}$ ergs. Since the estimated yield of thermal energy is so close to the estimate of the total explosive energy, Zolotov favoured a nuclear rather than a chemical explosion.

The burning sensations experienced by Semenov and Kosolopov, the melting of Ilich's metal ware—all these tend to lend support to the hypothesis. A fraction of a second after a nuclear explosion a high pressure, intensely hot and luminous shock front moves outward from the "fireball." However, if we consider purely *natural* phenomena it becomes difficult, in the light of all the apparent observed effects, to attribute the event to either a fission or a fusion reaction.

The Anti-Matter Theory

The idea that "anti-matter" might have been implicated has recently come to the fore. This is rather a complex business. Reducing it to barest essentials (and grossly over-simplifying) we can point to the hydrogen atom and its positively charged nucleus around which orbits a single negatively charged electron. The opposing charges cancel each other out and the atom, as a consequence, is left electrically neutral. In the equivalent "anti-hydrogen" atom an entirely opposite state of affairs prevails, *i.e.*, there would be a *negatively* charged nucleus and single positively charged electron. Physicists theorize that matter and anti-matter are mutually destructive. If the Tunguska "object" were of anti-matter it could hardly have originated *within* the Solar System, and it seems unlikely, if present cosmological beliefs have validity, that it could have originated in interstellar or intergalactic space.

In many respects the anti-matter hypothesis has a mantle of credibility for certainly the "thing" disintegrated most violently to be followed by shock and searing heat waves of an intense kind. Recently however doubts have been cast on this theory by Venogradov and other Soviet geochemists. Protagonists of the idea had stressed not only the great amount of energy released by the explosion but also the marked increase (7%) in the amount of radioactive carbon in the atmosphere. Venogradov measured the quantity of carbon near the epicentre of the explosion by the annular year "rings" in a 140-year-old larch tree. He found there was indeed an increase in the carbon content of the atmosphere but this amounted to only 2% near the epicentre in 1908.

It has further been shown by research workers in several countries that variations in the carbon content of the atmosphere have on occasions during the past 3000 years amounted to as much as 4%. Certain Soviet scientists now tend to attribute such increases to a corresponding decrease in solar activity. It was observed that the years in which increase in atmospheric carbon concentration took place were also those in which there were no appreciable changes in solar activity. In the years since 1908 the carbon concentration in the atmosphere has dropped fairly sharply. Had "anti-matter" really entered the atmosphere that June morning this would hardly have been the case.

Lastly we come to the most fantastic idea of all. A Russian scientist named Kasantev visited Hiroshima shortly after the destruction of that city by an atomic bomb. Some years later he visited the Tunguska region and was particularly fascinated by the similarity of much of the devastation

[*Concluded in adjoining column*

SPACE REPORT

A regular monthly review of Space Events and Technical Trends

Venus 4 Results

Even had the space station Venus 4 only passed through part of the atmosphere of Venus before burning up, the experts who planned the experiment would have been well pleased. This was made clear by Mstislav Keldysh, president of the U.S.S.R. Academy of Sciences, when he spoke at a press conference in Moscow on 30 October. Actually to have reached the surface of the planet, was, he said, a "huge success."

At the press conference a number of leading Soviet scientists told of the results of the experiment and some put forward their own views about the significance of the results.

Mstislav Keldysh said the fact that a terrestrial apparatus had floated down onto the surface of Venus opened up wide prospects for studying the planet. Clear radio signals had been received from the station throughout the whole of the descent.

During the descent provision had only been made for power to be supplied from storage batteries, since the nature of the light beneath the planet's cloud cover was unknown.

The maximum lifetime of the station as determined by battery power was 100 min, which was sufficient for making measurements of the characteristics of the atmosphere at different altitudes.

He stressed that the station had entered the atmosphere at the second cosmic velocity (the speed required to become a satellite of the Sun) and that no space vehicle had ever before entered even the cool atmosphere of the Earth at that velocity. When the velocity of the entry capsule had dropped from 11 000 to 300 metres/sec, the parachute opened. Just before reaching the surface of the planet, the velocity was three metres/sec.

Academician Keldysh summarized the main results of the flight as follows:

"For the first time a station has descended on to Venus and has transmitted information through the atmosphere at a distance of more than 75 million kms. This information has paved the way for the development of apparatus for fuller explorations of Venus."

He said it had been established close to the surface of Venus that the magnetic field of the planet could not exceed three 10 000ths of the magnitude of the magnetic field at the surface of the Earth. It had also been established that there was no radiation belt. The hydrogen corona of Venus was much weaker than that of the Earth.

Academician Alexander Vinogradov said water content in the atmosphere of Venus ranged between 0·1 and 0·7%. The lower atmosphere was not saturated with water vapour, the water being condensed in the planet's cloud layer. The oxygen content was some 0·4–0·8%. He added that the atmosphere probably contained small amounts of argon and other inert gases.

Deep space tracking station in the Crimea which maintained communications with Venus 4. Each of the coupled dishes has a diameter of 48 ft. Total weight of the receiver is 1,400 tons. At the time of atmospheric entry of the Venus probe the 250 ft dish aerial at Jodrell Bank also received signal data. British assistance was officially sought by the U.S.S.R. Academy of Sciences.

Academician Vinogradov said the Earth and Venus were very similar but that the development of their surfaces had proceeded differently because of difference in distance from the Sun. He visualized Venus as "a hot stony desert tinted with ferric oxide."

He expressed the view that Venus, lying closer to the Sun, in the course of evolution had evidently become warmer than 50° C. Intensive evaporation of water began, solar rays were absorbed in the infra-red section and heating of the atmosphere had intensified. When the temperature reached 250° C, all the carbon dioxide turned out to be in the atmosphere as a result of the disintegration of calcium and magnesium carbonates.

He imagined, he said, that the quantity of carbondioxide on Venus was the same as on Earth, the only difference being that on the Earth it was in the Earth's crust, whereas on Venus it has risen above the crust.

Astronomer Vladimir Prokofiev, of the Crimean Observatory, recalled that scientists had thought that nitrogen was the main component of the Venusian atmosphere, but it turned out that the atmosphere consisted almost entirely of carbon dioxide (90–95%) while the amount of nitrogen did not exceed 7%.

He explained that all the information about the composition of the atmosphere had been obtained at an altitude of 23–26 km.

"It can be considered that this relative composition is maintained down to the actual surface," Dr. Prokofiev said. At the place where the station landed, the temperature was 270° C, with a margin of error of ±7°.

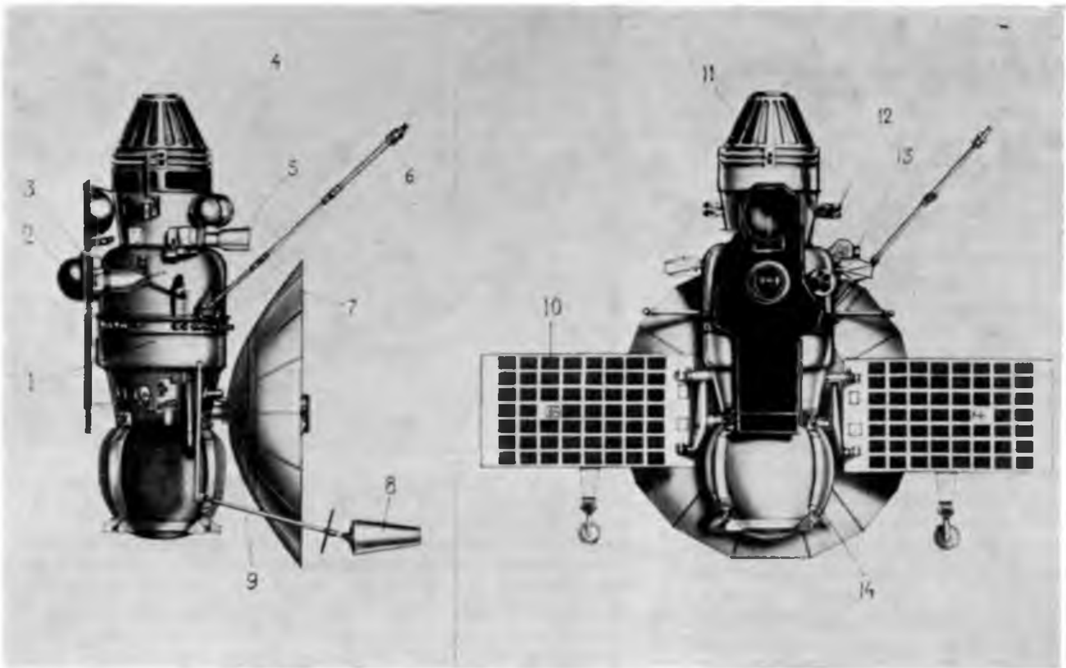
Geophysicist Alexander Obukhov explained that while Venus was covered with clouds, there was no rainfall. If the moisture content in the Venusian atmosphere was taken as 1%, he said, then the level of condensation must be at an altitude of 28 km. In that case big layers of clouds must exist, consisting of drops of water in the lower part. The general physical conditions for the condensation of moisture would be close to those observed in the Earth's atmosphere.

Concluded from page 48]

caused by the two events. Kasantev adheres apparently to the belief that a nuclear-powered star-ship was attempting to land in Siberia when its engines vaporized in a colossal blast!

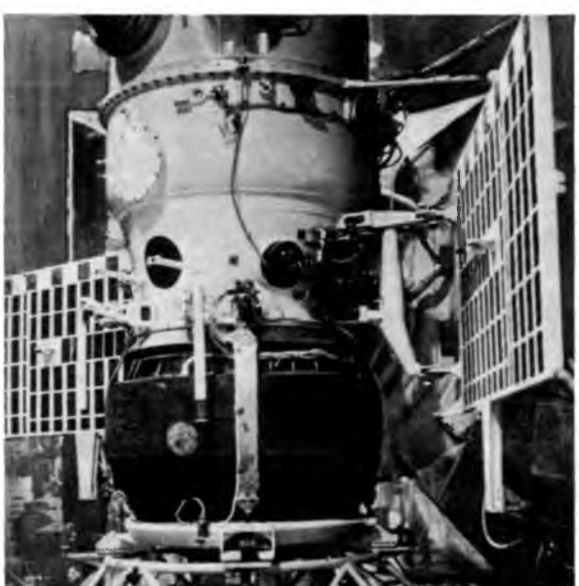
References

1. *Nature*, **56**, 595 (27/1/16).
2. *Jour. Br. Astr. Ass.*, **18**, 9, 354.
3. *Scientific American*, April 1931.
4. As told to Kulik on 30/3/1927 (*Nature*, **206**, 861, 29/5/65).
5. *Nature*, **206**, 861 (29/5/61).
6. *Nature*, **127**, 719 (9/5/31).
7. Krinov, E. L., *Solar System*, **4**, 208 (Univ. of Chicago Press, 1963).
8. Whipple, F. L., *Astrophy. Jour.*, **111**, 375 (1950).
9. Whipple, F. L., *Quart. Rev. R. Met. Soc.*, **56**, 287 (1930).
10. Fesenko, V. G., *Astronomickeskii Zhurnal*, **38**, 4, 577 (1961).
11. Encyclopedia Brittanica, 340–345, Vol. 15, 1953.
12. Alderman, A. R., *Mineralogical Mag.*, March 1931.
13. *Nature*, **129**, 782 (28/5/32).



All pictures Novosti Press Agency.

Principal feature of the 2439 lb interplanetary station Venus 4. Key: 1. Orbital module; 2. Astro-orientation transducer; 3. Constant solar-orientation transducer; 4. Gas bottles; 5. "Sun-Earth" orientation transducer; 6. Magnetometer tranducer and arm; 7. High angle parabolic antenna; 8. Low angle antenna; 9. Radiator of temperature control system; 10. Solar cell panel; 11. Engine for mid-course correction; 12. Micro-thrust units of astro-orientation system; 13. Cosmic ray counter; 14. Ejectable entry capsule.



Soviet interplanetary station Venus 4 which achieved the first soft landing of an instrument capsule on the surface of Venus on 18 October. The 1 metre diameter capsule is held by straps to the parent vehicle. For additional details see p. 15 of January issue.

"If a minimum quantity of moisture (0·1%) is assumed," he added, "the theoretical level of the clouds must be raised to 32 km. They will be less dense and will consist of ice crystals."

Alexander Obukhov stated that owing to the high refracting ability of carbon dioxide, compressed to 20 atmospheres, conditions of "super-refraction" existed on the surface of Venus and the curvature of light rays was greater than the curvature of the planet itself. "A horizon in the usual meaning of the word does not exist," he said. "To an observer it would seem that he was at the bottom of a gigantic bowl."

Replying to questions put by press correspondents, Valentin Ishevsky, an expert in the technical sciences, said: "The station completely carried out its programme. No further explorations were intended." He explained that in order to protect the station from overheating special heat-resistant materials had been used, including components with a high melting point and strong binding elements. "Those are secrets of the firm," commented Mstislav Keldysh with a smile.

Academician Alexander Vinogradov did not rule out the possibility of organic substances existing on Venus. He said that "radiogenic processes may be under way on Venus producing organic substances."

At the press conference Academician Keldysh was asked what, in his opinion, was the most important achievement of Soviet science in recent times. He replied that "the most outstanding event has been the experiment carried out with the help of the automatic station Venus 4." Other notable events, he added, were the commissioning of a number of accelerators, notably in Erevan, Armenia and in Serpukhov, near Moscow.

One of the questions asked at the press conference was the following: "What obstacles still exist to manned flights to other planets?" "Many," replied Mstislav Keldysh. "But in principle the problem is already clear." He said he could not say when man would fly to Venus. Preliminary explorations with the help of automatic probes would be necessary. "But I don't rule out the possibility of flights to that planet."

Surface of Venus

The surface of Venus appears to be a dry hot desert, according to Soviet scientist Dr. Vladimir Prokofiev of the Crimean Observatory. The data received from Venus 4 confirmed to a considerable extent the findings of optical and radio-astronomers. However, he was surprised by the absence of noticeable quantities of nitrogen in the planet's atmosphere.

"We expected to find a lot of carbon dioxide there," he said, "but the main component of the atmosphere should have been different. According to the observations of the Soviet scientist Nikolai Kozyrev, it should have been nitrogen, but as it turns out nitrogen is virtually non-existent. This alters considerably our ideas about the Venerian atmosphere."

Dr. Lev Tauson, director of the Irkutsk Institute of Geochemistry, said that scientists were now very close to being able to study the chemical composition of the Venerian atmosphere and surface rocks, and then possibly its deeper zones. The absence of a magnetic field indicated that the composition of Venerian rocks differed little from the terrestrial. He said it was possible that there were basalt-type rocks on Venus and probably others.

In the opinion of corresponding member of the Soviet Academy of Sciences Nikolai Krasilnikov, life may exist on Venus in the form of micro-organisms. Information transmitted by Venus 4 was in favour of such a possibility. "There are microbes on Earth which withstand temperatures of 130° C and more," he said. "Heat resistant varieties, living on Earth can theoretically exist in conditions of the Venus atmosphere."

Krasilnikov went on to say that on Venus, as on our own planet, there were obviously sharp fluctuations and differences in temperature at different parts of the surface. To a certain extent, this determined the variety of possible micro-organisms.

In Krasilnikov's opinion, the high atmospheric pressure on Venus could not be an obstacle to the life of micro-organisms. Observations and experiments had shown that many bacteria on Earth could withstand pressures of up to 100 atmospheres.

The gaseous composition of the Venerian atmosphere also allowed the existence of micro-flora, because it included components necessary for life: oxygen, water vapour and carbon dioxide. "In our laboratory we keep organisms alive with an even lower content of oxygen," he said. "We have on Earth quite a number of forms which consume negligible quantities of oxygen. It cannot be precluded that such forms exist on Venus too."

Noting that micro-organisms "settle" on splinters of rocks, he recalled that millions of various forms had been detected on bare rocks in highland regions of the U.S.S.R. where, it would seem, not the slightest conditions for life existed.

Krasilnikov said the information transmitted by Venus 4 made it theoretically possible to admit the existence of a comparatively varied micro-flora. It was possible that a similar atmosphere with a low oxygen content and unfavourable conditions for life had prevailed on Earth at one time.

Soviet Man in Space

Writing in the magazine *Aviatsia i Kosmonavtica* Soviet cosmonauts Gagarin, Titov, Nikolayev and Leonov say that the reliability of a spaceship will be considerably increased by achieving the best combination of the cosmonauts' abilities and the characteristics of the control systems. The reliability of a fully automated spaceship designed to circle the Moon and return to Earth is only 22%, the cosmonauts write. But with a man taking part in the piloting of the spaceship reliability could reach 93%.

They believe that circumstantial evidence on whether or not life exists on Mars or Venus cannot be a satisfactory substitute for visits by humans to those planets. It is the business of humans to study the surface of the planets and to search for unknown forms of life.

Noting that the rendezvous and docking of spaceships will become standard practice, the cosmonauts say this will be necessary in order to assemble big spaceships and orbital stations, to refuel spaceships leaving on distant voyages and to make repairs.

Big problems have to be faced in the transition to the next stage of spaceflights, they stress. It will require the construction of spaceships of much more advanced design and thorough flight preparations. Existing experience must be analysed and maximum use made of it. This is not as simple as it might at first appear. The slightest chance error may grow into a major calamity. Paying tribute to cosmonaut Vladimir Komarov, who lost his life last April when landing the spaceship Soyuz 1, the cosmonauts write: "Our only consolation is that his life was not lost in vain. We know very well that our success in new flights to the stars will be helped by his knowledge, experience and boundless courage."

First Franco-Soviet Space Test

Temperature of the upper layers of the atmosphere has been measured by Soviet meteorological rockets carrying French research equipment. The rockets were launched from Kheysa Island, Franz-Josef Land, in the Arctic. The aerology service of the French National Research Centre equipped the heads of the Soviet rockets with devices which made it possible to create artificially luminescent sodium clouds at altitudes of 75 to 112 miles.

In earlier experiments the French scientists had observed sharp changes of temperature in the upper layers of the atmosphere at an altitude of about 75 miles. They believe it is possible that during the period of the Northern lights the temperature in these layers changes as a result of bombardment by charged particles. The experiment on Kheysa Island was made to check this theory.

Value of Space Research

Is the world spending too much money on space exploration? This question, frequently asked in one form or another in all countries, was recently put to cosmonaut Konstantin Feoktistov by a correspondent of the *Novosti Press Agency*. This was his reply:

At first sight this question seems quite logical. In many parts of the world people are still without many of the bare necessities, such as a roof over their heads, adequate and regular meals, clothing and footwear.

That is why we may often hear such questions as these: "Of what practical use is space exploration for man's life on the Earth;" "What does mankind need space for, when it has not made life satisfactory everywhere and when many countries have not got rid of such calamities as hunger, diseases, a high mortality rate and illiteracy on a mass scale;" "Wouldn't it be better to use the money that is being spent on rockets and satellites for building hospitals, schools and new factories;"

All these questions may be answered in the following way:

In the first place, space exploration must not be set in opposition to people's efforts to improve their life, for these are two aspects of human progress which are not mutually contradictory.

Secondly, space exploration, like any other major scientific discovery—remember electricity or the creation of nuclear power—is of immediate use. Favourable results can already be seen today, at the very outset of space exploration.

Meteorological satellites make it possible to forecast the weather with a high degree of reliability, which is very important for agriculture. Navigation satellites help ships to find their exact positions and help to ensure safety at sea.

Relay satellites are opening up new vistas for communications and television. Thanks to satellites of the Molniya I type, we now have direct television broadcasts from Moscow to Vladivostok and from Vladivostok to Moscow.

The main benefit which space exploration brings man today, however, is that the creation of carrier-rockets, artificial satellites, space laboratories and space probes is leading to the rapid development of the most progressive fields of science and technology: cybernetics, physics, biology, medicine, radio engineering and aerodynamics. And the results are exerting a favourable influence on everyday "earthly" life and are helping people to improve it in every possible way.

Last but not least, the third reason which would prevent us from stopping space research, even were we to decide to "save money" on it, is inherent in man himself. The point is that man is so constituted that he cannot be kept away from the urge, or it may be said, the temptation to think.

If man has opened a door into the unknown, he will walk through that door whatever it may cost him. There is a great creative trait in man which has made him travel the road from cave to skyscraper, and from the initial source of energy—a wood fire—to the atomic power station.

Already today many people consider that if man penetrates into space, he will obtain and learn to accumulate the greatest energy of all—solar energy—and this will transform the Earth.

Vortical Solar Flares

Solar flares move in vortical trajectories, according to the Soviet astronomer Vladimir Chistyakov. His conclusions are based on observations carried out at the Ussuri Solar Observatory in the Soviet Far East. The discovery is of more than theoretical interest because many phenomena on the Earth and in space particularly affecting communications, are influenced by activity on the Sun.

Solar flares, often up to 6000 miles across, last on the average for 2 days. Chistyakov believes the discovery of their vortical formation confirms theories of a connection between their appearance and an intensification of magnetic fields. The Ussuri Observatory, which is at present engaged in the study of the magnetic fields of sun spots, is on a meridian which has practically no other astronomical research centres. Standing on a hill top, it operates between 220–290 days a year. Its equipment includes a telescope with a diameter of 44 cm and a focal length of 17·5 cm.

Saturn's Rings

Using an 80 cm meniscus telescope, the Soviet astrophysicist Rolan Kiladze has measured the thickness of the rings of Saturn by the photometric method. He believes the rings are approximately 3000 ft thick; they were previously thought to extend for over six miles.

The scientist bases his estimate on forty photographs taken during the passage of the Earth through the plane of Saturn's rings. The photographs enabled him to carry out a mathematical analysis of the varying brightness of the rings, thereby measuring their thickness, which had not previously been possible using conventional optical instruments.

Analysis of the ratio of brightness of the light and dark sides of the rings shows that solar light does not penetrate them, suggesting that the substance of which they are composed is of a high density.

In the December issue of "Spaceflight" (page 409), it was announced that a new satellite of Saturn had been discovered. This is Saturn's 10th known satellite, not the 12th as stated in the headline to this item.

World's Biggest Telescope

When the big astronomical telescope now being built in Leningrad is completed, the 200-in Hale reflector on Mt. Palomar will no longer be "the world's largest telescope." The 850 tonne Soviet instrument has a mirror of 6 metres (236-in) diameter weighing 42 tonnes. Mechanical parts of the 130 ft high telescope have already been assembled.

The electronically-controlled telescope tube weighs some 300 tonnes. It will detect a light of one candle power at a distance of over 15 000 miles.

Designed by a group of scientists and engineers led by Lenin Prize-winner Bagrat Ionnisiani, the reflector will be used to study objects of small luminosity and to observe variable stars, novae, supernovae, planets, comets, the Moon and "artificial celestial bodies." Apart from photography of the heavens, there will be opportunities for spectrographic, colorimetric and polarimetric research. Special devices "ensure the protection, microclimate and cooling of the mirror."

The instrument will be assembled at a site in the Caucasus at an altitude of more than 2000 metres (6560 ft) above sea level.

Fireproofed Apollo Spacesuit

First production model of the Apollo spacesuit incorporating changes recommended by the Apollo 204 Review Board was delivered to the Manned Spacecraft Center at Houston, Texas, in October. The re-designed suit, designated A-7L, is based on the original A-6L Apollo pressure suit with a number of changes, mainly concerned with reducing the fire risk to astronauts.

Wherever possible, flammable materials have been replaced with non-flammable or low flammability materials. The outside layer is Beta fabric, a non-flammable fibreglass cloth, instead of Nomex high temperature nylon. Beta fabric has also been used instead of nylon to sheath electrical cabling.

A Nomex liner has replaced the more flammable nylon liner of the previous suit. Flammable poly-urethane has been replaced with non-flammable carboxy-nitroso rubber for boot soles and by a silicone material for helmet, vent and shoulder comfort pads. Fire resistant Kapton/Beta fibreglass insulation has been substituted for the previous aluminized mylar-dacron insulation.

The re-designed Apollo suit, in addition to its greater fire-resistant property, is more comfortable and more mobile than the original A-6L model. A thermo-meteoroid protective covering is fabricated into the suit replacing the more cumbersome two-piece thermo-meteoroid garment (TMG), to be worn over the previous suit.

The re-designed Apollo suit eliminates pressure points experienced with the earlier suit in the thigh, under the arms and over the shoulder. As in later model Gemini suits, the new suit will have a double lock for helmet, glove and umbilical hose disconnect.

The Apollo suit's outward physical appearance is changed. It is white rather than blue, and it has gray patches of metallic fibre cloth over the elbows, knees, back and shoulders to protect the Beta fabric from abrasion.

The new suit is planned for use in all manned Apollo missions. It will be worn during pre-launch and launch phases of the mission and during re-entry. Throughout

much of the rest of the flight, if all is going well, the crew may remove the pressure garments and don light-weight, unpressurized Beta fabric flight suits.

Apollo pressure suits are manufactured by the International Latex Corp., Government and Industrial Division of Dover, Delaware, under contract to the Manned Spacecraft Center. The Beta fabric application to the re-designed suit was developed by Owens-Corning Fiberglas Corporation of Ashton, R. I., under contract to MSC. Nomex and nylon components of the suit are manufactured by the E. I. duPont de Nemours and Co. Incorporated of Wilmington, Delaware.

Surveyor Lunar Test

A test conducted with the Surveyor 5 spacecraft on the lunar surface has filled an important blank in the information needed by engineers planning the Apollo programme for a manned landing on the Moon. Photographs of the surface immediately under the rocket nozzles indicate that no craters were made on the lunar surface and no appreciable dust cloud was created by the exhaust. The report was made by officials of NASA's Office of Manned Space Flight.

Surveyor 5 was launched by the National Aeronautics and Space Administration on 8 September 1967 from the Kennedy Space center, Florida, and achieved a soft-landing on the Moon on 10 September. The test involved firing the small vernier engines to observe the effect of the rocket exhaust as it struck the lunar surface during a burn of 0·2 sec.

A picture taken before the rocket firing showed four or five clumps of lunar soil in the area; after the rocket operation only one clump remained. Only one "little blob" of dust was detected on the Surveyor's outer surface and this may have been deposited when the spacecraft landed.

This information indicates there will be no problem associated with the effects of the rocket exhaust of the Lunar Module which will carry two astronauts to and from the Moon. There was a lack of data to indicate whether the rocket exhaust would "dig a hole" in the surface immediately under the landing spacecraft, or whether it would scatter dust around the spacecraft and seriously curtail the visibility of the two astronauts returning to Earth.

The Surveyor vernier engines were operated at a thrust of 17, 20 and 27 lb. By scaling up these figures arithmetically, engineers can apply them to the larger Lunar Module descent engine to be used in the manned lunar landing.

Breathing Chlorella Oxygen

A woman scientist at a Siberian Institute has spent a month in a hermetically sealed cabin where the air was constantly renewed by a chlorella "hot house." Millions of cells of algae, of the "Cosmic" strain, absorbed the carbon dioxide released in breathing, and in the process of photosynthesis converted it into oxygen. For the first time water in a closed biological system was passed through a chlorella cultivator and was subjected to further chemical purification.

In the experiment an attempt was made to solve some problems connected with setting up an artificial system which would serve as a biological closed cycle in outer space and would discharge a similar function as the Earth's atmosphere. The idea of setting up a "hothouse" in spaceships was advanced in his time by Konstantin Tsiolkovsky, the Soviet founder of cosmonautics.

Three stages are necessary for a self-balancing system: the closed "man-vegetation" cycle must be implemented for atmosphere, water and food. The first two stages have been implemented by the Siberian scientists. For this purpose they created a compact automated chlorella cultivator with high productivity and also a sensing and controlling system which automatically maintained the necessary conditions.

The chlorella cultivator is a completely closed lantern with a powerful xenon lamp. The interior walls are mirrors which reflect virtually all the light. The chorella lives in a 5 mm cavity between large plates of organic glass arranged like a jabot around the xenon lamp. The total surface of the area in which the chlorella is placed is 107 ft^2. About 500 g of algae would produce enough oxygen to satisfy a man's requirements.

The algae responded to the respiratory conditions of the scientist. When she was sleeping, the chlorella were less active. The water in the closed system conformed to the highest sanitary standards of drinking water. When the scientist began receiving the water from the closed system she was unable to tell the difference between this and ordinary water from a mains supply.

Other experimenters had earlier spent several days in the chorella atmosphere of the cabin; and before that purified water was tested on animals.

The experimental programme also has its terrestrial application. It is helping to lay the foundations of controlled biosynthesis which may result in automated processes for obtaining medicines, vitamins, protein and other valuable substances.

Nimbus Sensing System

An advanced direct sensing system for the Nimbus D Meteorological Satellite, scheduled for launching in 1970, will be developed by Radiation Incorporated under a $2 981 000 NASA contract.

Called Interrogation Recording and Location System (IRLS), the experiment involves development of a satellite-borne device and remote platform electronics to obtain measurements of atmospheric and other data "from fixed and free floating sensory platforms," including balloons and buoys. The data from the platforms, recorded by Nimbus, will be relayed to its tracking stations for use by scientists. Work will be performed under the direction of the NASA Goddard Space Flight Center at Greenbelt, Maryland.

Soviet Meteorological Sputniks

The meteorological sputniks Cosmos 144 and Cosmos 156 are collecting a hundred times as much information in one orbit of the Earth as that coming in from all conventional meteorological stations of the world, which total more than 10 000, says Mr. Georgi Golyshev, deputy head of the U.S.S.R. Hydro-meteorological Service.

Cosmos 144 was launched on 28 February 1967 and Cosmos 156 on 27 April. The launchings marked the beginning of an experimental meteorological system of two sputniks operating simultaneously with a ground complex for control, reception, processing and distribution of information from orbit.

Golyshev notes that in setting up such a space system it is important that satellites should operate over pre-set and interconnected orbits and that the characteristics of these orbits should be identical. Thanks to efficient rocketry the high circular orbits of the two sputniks differ only by a fraction of one per cent and the difference in their transit period is only a few seconds.

Instruments of the sputniks have been performing faultlessly and the enormous amount of information received has been used in the day to day work of the hydro-meteorological services in the U.S.S.R. and abroad.

"Solar Flare" Experiments

Laboratory experiments simulating conditions that cosmonauts may encounter during solar flare activity are being conducted in the Soviet Union. The apparatus consists of a chamber divided into compartments in which the reactions of animals exposed to radiation are observed by television.

The radiation is provided by a "gamma-cobalt installation." In all tests to date the overall radiation dose has been 900 roentgen. It was established that during a solar flare "special pharmaco-chemical substances acted on white mice in the same way as during ordinary irradiation." Object of the research programme is to determine exhaustively all possible variants of irradiation experienced during spaceflights.

Nuclear Rocket Contract

The Space Nuclear Propulsion Office of Germantown, Maryland, has extended its contract with Aerojet-General Corporation of Sacramento, California, for development of nuclear propulsion.

Aerojet, which has been the prime contractor since 1961 on the NERVA project, will receive an estimated $14.7 million under the interim contract for work performed until 30 November. The Space Nuclear Propulsion Office, a joint operation of the Atomic Energy Commission and the National Aeronautics and Space Administration, receives $6.8 million of the funds on this contract extentions from NASA, the balance from AEC.

Stratospheric Observatory

Leningrad astronomers have again photographed the Sun free of atmospheric interference by using a large telescope in a balloon-borne automatic observatory. A similar observatory was sent up in November 1966, successfully beginning Soviet research by means of stratospheric telescope observations.

The second solar observatory included a large telescope, a spectrograph, photographic, television and electronic equipment, and telecontrol and telemetric systems. Many pictures and spectrograms of the sun's surface were obtained and have been sent to Pulkovo Observatory for scientific processing and analysis.

Designed for repeated use, the stratospheric observatory is now being prepared for further ascents.

Uzbek Cosmic Ray Research

The behaviour of cosmic rays "of super-high energies of up to 10 million million electron volts" will be studied at a research station of the Uzbek Academy of Sciences in the Turkestan mountains some 170 miles from Tashkent. The station is situated 10 500 ft above sea level. The scientists there hope to study the process of the birth of super-heavy particles of mass dozens of times greater than that of protons, and also the nature of the interaction of nuclear particles during their collision with atomic nuclei.

The installation, which has an effective area of about 100 ft^2, has an ionizing calorimeter consisting of 300 ionization chambers, a number of Cherenkov counters and an ion filter about 7 ft thick.

It is at present beyond the power of any terrestrial accelerator to obtain particles of super-high energies. Great attention is therefore being paid to building apparatus of this kind for the study of cosmic rays in which particles are speeded up by natural accelerators to colossal energies.

Experiments in Space Anabiosis

Writing in the journal *Aviatsia and Kosmonavtika* cosmonaut Dr. Boris Yegorov says that experiments in anabiosis—artificial slowing down of the physical processes of the organism—offer the possibility of protecting cosmonauts from the effects of acceleration during long flights.

Dr. Yegorov points out that experiments with animals have shown that their resistance to acceleration increased many times by the use of anabiosis.

He referred to observations made during flights lasting over 10 days which resulted in dehydration of the organism and reduction of the muscle mass and of the density of the osseous tissue. This had been evident during the 14-day flight of the American astronauts, and similar data had been obtained from the flight of the dogs Veterok and Ugolyok in the Soviet sputnik Cosmos 110.

While these effects can be regarded as a reaction of the organism to weightlessness and its adjustment to changing conditions, it is quite possible that having reached a certain level, the cosmonaut will feel fit, Dr. Yegorov writes. But the physical changes resulting from acceleration during landing may have very negative effects leading to quite serious disorders, if special protective measures are not taken. He thinks that pharmacological preparations and special anti-*g* devices—both of which are envisaged in the idea of anabiosis—may give some protection to the cosmonaut. But Dr. Yegorov concludes that such a solution is at present hypothetical, as the conjectures are at present supported only by experiments on animals.

Aerospace Safety Panel

The National Aeronautics and Space Administration has appointed an interim working group composed of Dr. Alfred J. Eggers, Dr. Floyd L. Thompson and Gen. Jacob E. Smart, to review NASA safety procedures and prepare a plan under which the Administrator can proceed to establish an Aerospace Safety Advisory Panel.

Gen. Mark Bradley, Garrett Corporation, will serve as a consultant to the chairman, Dr. Eggers. The action is taken to implement Section 6 of Public Law 90–67 (the NASA Authorization Act for Fiscal Year 1968).

Eggers is Special Assistant to the Administrator and Deputy Associate Administrator for Advanced Research and Technology. Thompson, Director of NASA's Langley Research Center, Hampton, Virginia, served as chairman of the Apollo 204 Accident Review Board. Gen. Smart is NASA's Assistant Administrator for Policy.

Last Saturn Stages

The National Aeronautics and Space Administration has purchased nine Saturn 5 third (S-IVB) stages from the McDonnell-Douglas Corporation of Santa Monica, California at a cost of $146.5 million. This purchase completes the requirement of S-IVBs for the fifteen currently approved Saturn 5 and twelve Uprated Saturn 1 launch vehicles in the Apollo programme.

The work assignment on this agreement is to be completed in May 1970. First of the nine stages is to be delivered to NASA in April 1968.

The 200 000 lb thrust S-IVB is built for both the Uprated Saturn 1 and Saturn 5 rockets. With this supplement the total S-IVB contract for both vehicles is $957 182 093. NASA has already received eight of the stages for use as the second stage of the Uprated Saturn I and three for Saturn 5.

The Rolamite

An American engineer has invented a device that performs a variety of mechanical functions normally achieved by a combination of conventional springs, levers and wheels. The device, named "rolamite," is described as having the same promise for mechanics as the transistor had for electronics. It employs two or more rollers in a flexible band or tape to perform numerous mechanical functions.

Invented by Donald F. Wilkes, a mechanical engineer of the Sandia Corporation of Albuquerque, the rolamite should find many applications both on Earth and in space. The inventor says he has found at least fifty-four applications for its use in relays, bearings, speed changers, pumps, pistons, dampers, shock absorbers, toys and even jewelry. Special advantages include the virtual absence of friction, no need for lubrication, lack of sensitivity to contamination, inexpensiveness and possibility of miniaturization. Rolamites appear particularly suited for use in space, where conventional lubricants break down.

Sandia Corporation say the rolamite "appears to be an elementary mechanism as basic as the lever, wheel, crank, spring or hinge. Components involved are a rectangular frame, a relatively long and flexible band, usually metallic, attached to the frame, and two rollers. When the rollers are inserted into the band, it is formed into an "S" shape.

The company points out that the design tends to decrease friction in usage, rather than increase it as with conventional devices. The combination of low friction and absence of lubrication means rolamites could be made extremely small in systems which require movement of some mass to perform a function.

Vertical Space Probe

A rocket carrying apparatus for a vertical probe of the Earth's atmosphere was launched in the Soviet Union on 12 October. The last stage of the rocket took the apparatus to a height of 4400 km (over 2730 miles). Object of the experiment was to study the upper layers of the atmosphere, the ionosphere and near-earth space and in particular to obtain data on the characteristics of the ionosphere at different altitudes (*i.e.*, concentration of electrons and positive ions and temperature of electrons), and the general intensity of cosmic rays and doses of radiation and the density of hydrogen molecules at different altitudes.

Apparatus in the probe included special materials ensuring accurate measurements." After launching the probe into the planned trajectory, the rocket was moved a considerable distance away by a special device so that the ejected gases should not affect measurements in the region of space chosen for study.

The probe carried a telemetry system for transmitting information and radio devices for measuring the trajectory. All the instruments and systems aboard functioned normally during the flight. It was the first time such complex explorations had been made at these altitudes.

Experiment in Complete Immobility

Two young men—Roman Kotsan of Chernovtsy (Ukraine) and Stasis Mostvilas of Vilnius (Lithuania)—have spent more than two months in a state of complete immobility. This "hypo-dynamic" experiment, in the opinion of Soviet scientists, opens many new fields in medicine. One of the objects of the experiment was to approach as closely as possible the conditions of spaceflight during which problems of weightlessness appear, as well as a sharp drop in the load on body and muscles.

Three men volunteered for the experiment. They had to lie on specially constructed swings designed in such a way that the board, no matter how it was pushed, would always remain in a strictly horizontal position. During the experiment the men ate, read and conversed.

On the 23rd day their bodies began to ache and it took all their will power to continue to lie on the swings. Several days later the third man in the experiment began to lose orientation in time and space and the doctors ordered him to stop the experiment. A week later the other two suddenly felt much better. Their bodies, having tired of the struggle against idleness, adjusted themselves to life without work and resistance.

After the experiment the men could not stand up; their legs buckled under them. By the evening of the second day they could sit up. Several days later they had fully recovered their strength.

Emergency Oxygen System

A working model of an emergency system using hydrogen peroxide to provide oxygen and water in a spacecraft has been developed by Air Products and Chemicals, Incorporated, of Allentown, Philadelphia. Hydrogen peroxide has already been used successfully in space as a fuel for attitude control rockets.

The system was developed under contract from the Aerospace Medical Research Laboratories at Wright-Patterson Air Force Base to determine the feasibility of hydrogen peroxide as a stand-by source of oxygen and water during extended space flights. The Air Products studies showed that a hydrogen peroxide system weighed 25 to 30% less and took up less volume than separate emergency supplies of oxygen and water.

The life-support decomposes hydrogen peroxide by means of a catalyst, then separates the decomposition products into water and oxygen by means of a newly-developed phase separator capable of operating under weightless conditions. The system is reliable and requires no external power source. It supplies breathable oxygen and drinkable water without further purification.

The 28-lb laboratory model would be able to supply oxygen and water for one man for at least 24 hr in existing space capsules. A model designed for airborne use would weigh considerably less.

Much larger amounts of hydrogen peroxide could be used with the same weight of hardware to increase the system's operating time.

The working model will undergo further tests at Wright-Patterson Air Force Base before being considered for use on lunar missions.

Cosmos 166

The Soviet satellite Cosmos 166, launched on 16 June, is now identified as a research satellite designed to study short-wave emissions from the Sun. The satellite worked for about three months and gave scientists much statistical data on solar X-ray flares and their relationship with optical flares. Elektron 2 "also recorded the existence of a special class of X-ray flares not accompanied by 'optical' flares observable from Earth." According to a Soviet report, " . . . by recording the X-ray flares, it is possible to warn cosmonauts of the approach of a radiation hazard—streams of corpuscles. This warning will enable spacecraft crews to take the necessary protective measures."

A Space Policy for Britain

Despite the activities of ELDO, ESRO and the Conférence Europeen des Telecommunications par Satellites (CETS), Europe has yet to play an effective role in space technology. Lack of purpose at the political level, and a stubborn refusal to establish a viable European space programme, are root causes of the waste, frustration and general dissatisfaction that surrounds this increasingly important field of European co-operation. The Council of the British Interplanetary Society feels that an important opportunity to place these problems—as they affect Britain—before Parliament was missed when the Parliamentary Estimates Committee, in its 13th report,* considered the topic of "Space Research and Development."

In this highly controversial report cost-effective programmes bearing on ELDO and Europe's future in an age of rapid technical advance received a negative response (e.g. "The United Kingdom should not take part in the CETS programme for a television distribution satellite."). Once again the B.I.S.—whose original recommendations for a Euro-Commonwealth communications satellite programme were placed before the (then) Conservative Government in February 1960—urges the adoption of space programmes which will guarantee an effective contribution by Britain and her European partners. The following lines of action are advocated for UK/European initiatives in space, which amplify previous B.I.S. recommendations to H.M. Governments in the light of events.

An Opportunity for Europe

Important developments of vital concern to every man, woman and child resulted from the first decade of space activity. The satellite is becoming a significant tool of mankind. Already we see its influence in revolutionary advances in global telecommunications, the precise navigation of ships and aircraft, weather forecasting, ice surveillance and the advance warning of destructive storms. Apart from widespread benefits to the community at large, these developments have the widest commercial significance; and as yet we are only on the brink of opportunities to exploit, as well as to explore, the space frontier.

Far from being a waste of human resources, investment in space technology is now seen to be having the widest influence, affecting fields as diverse as medical research, education, metallurgy, agriculture and mineralogy.

In the 1970's direct-broadcasting satellites offer a means of spreading education widely to underdeveloped countries; air-traffic control relayed from space-satellites will make long-distance travel safer in the supersonic age; and a whole range of Earth-related applications await the use of observation satellites surveying the natural resources of our planet. Improved agricultural crops, ecology, hydrology and the exploitation of mineral and marine resources promise monetary returns many times the cost.

Significantly, some of these benefits should affect underdeveloped countries more than the major powers, since they reflect directly upon more efficient food production and the exploitation of hitherto untapped mineral, oil and other natural resources in remote parts of the world. It is against this background of opportunity and advancing technology that Europe must assess the importance of joining the mainstream of space development.

* *13th Report from the Estimates Committee, "Space Research and Development," H.M. Stationery Office, London, 38s.*

International Programmes

Space participation is expensive. It therefore demands the most careful definition of aims consistent with available financial and technical resources. At present European space activity remains confused, unplanned and ineffectual despite 6 years' development in ELDO and ESRO. This is wasteful of talent and hardwon resources. It also creates the kind of environment that breeds disenchantment in the minds of first-class scientists and technologists and effectively contributes to the "brain drain."

Last year Britain spent more than £20 million on space, mostly in the international field. This is roughly 1% of the United States space budget. It is very questionable whether the U.K. taxpayer received the same value for money as his U.S. counterpart; and worse there does not appear to be any prospect of his doing so under standing arrangements in Europe. It is imperative that this situation is remedied at the earliest possible opportunity.

Although we should not expect immediate returns for our investment, maximum attention should be paid to areas which promise clear economic returns eventually. One such area is communications satellites in which Europe must quickly demonstrate competence or abandon an important commercial future.

It should be recognized that a commitment to an independent European communications satellite programme (related to the international Intelsat consortium) at once *fixes a requirement* to develop a launcher capability from which to evolve further branches of space competence.

Until a specific requirement is placed for a European communications satellite, we cannot begin to talk of cost-effectiveness in terms of space launchers being developed in the ELDO programme. At present the Organization's only customers are France and West Germany which have taken options on two vehicles for launching their joint Symphonie communications satellite. This situation needs to be resolved quickly if ELDO is not to face another crisis of confidence. Swift action is needed to ensure that countries participating in CETS (Conférence Européene des Télécommunications par Satellites) have a stronger bargaining position in Intelsat, prior to negotiations affecting re-constitution of Intelsat and establishment of a permanent organization in January 1970. The following actions are recommended:

(1) Establish a European Space Agency as a central planning and contractual authority with a separate budget, combining interests of ELDO, ESRO, CETS, etc., maintaining liaison with national programmes, NASA., Intelsat, etc.

A total budget of £80–100 million p.a. is assumed, of which the U.K. share would be 25%.

(2) Seek adoption of Franco-German Symphonie comsat project as ESRO/CETS "first-generation" experimental satellite.

(3) Extend ESRO/CETS proposal for TV-distribution satellite to "second-generation" concept suitable for European commercial application in (possible) Eurovision regional system, placing contracts with industry for design and preliminary development.

(4) In forthcoming Intelsat negotiations for permanent world comsat organization, ensure provision for development of separate regional telecommunications systems (*e.g.*, a system related to Eurovision under European management) but integrated with the overall Intelsat programme.

(5) Establish European Communications Satellite Corporation (Eurosat) partly financed by governments and partly by private investment, to allow further development of satellites and pay for ELDO launchings.

(6) Develop a family of ELDO launchers according to predicted European telecommunications requirements between 1970–85 (*i.e.*, progressive development of Europa launchers). Ultimately this will provide a powerful Earth orbital capability (*i.e.*, several tons of payload in close-orbit) from which to develop other space projects, such as recoverable launch systems serving both scientific and commercial purposes.

(7) Undertake a new assessment of requirements and opportunities for scientific satellites and space probes, relating these to available payload capability of ELDO launchers and smaller launchers derived from the British Black Arrow and French Diamant B.

(8) Make a study of long-term techniques likely to reduce the overall cost of space activity, *e.g.*, recovery and re-use of launch vehicles (including a cost/efficiency comparison between winged, lifting body and ballistic methods), and advanced propulsion systems. This should be backed up with the necessary technological development in all aspects.

(9) Make a full assessment of future opportunities for collaboration with U.S. and Soviet space programmes.
(These would affect areas which, by their nature, have the widest international importance. *E.g.*, Earth Resources Observation Satellite (Eros) programme, affecting agriculture, water conservation, oceanography, geology, etc.; satellite techniques for navigation and sea and air traffic control; Apollo Applications Programme, affecting more penetrating man-monitored studies in astronomy, biology and physical sciences.)

National Programme

The importance of maintaining a national space programme in individual countries, while at the same time participating in broader international projects, is often misunderstood. A national programme is necessary in order that competence in various basic space techniques should be sufficiently developed, making it possible for home industries to compete realistically for international contracts. France, which already has a well-coordinated space programme within the Centre National d'Etudes Spatiales (CNES), has already demonstrated its competence and hence has secured a higher proportion of ESRO contracts than the U.K.

Attention should be paid to achieving a proper balance of expenditure between national and international effort to ensure that the overall effect is complementary. We are of the opinion that a ratio of 50/50 expenditure would be appropriate, or possibly 40/60 in favour of international programmes.

The following actions are recommended:

(1) Establish a national space budget—excluding contributions to ELDO, ESRO and CETS—of £20–25 million p.a.

(2) Continue development of small national launcher Black Arrow for the double purpose of achieving larger orbital payloads and exploiting new propulsive techniques at the research and development level. This would look towards new requirements for larger European space requirements in the 1970's (*e.g.*, development of ELDO B launchers employing lox/hydrogen top stages).

(3) Seek to apply Black Arrow (and French Diamant B) in support of international programmes instead of relying on American launchers (Maximum cost-effectiveness depends on European launchers achieving the maximum possible usage).

(4) Black Arrow development also holds open the option of using the same basic vehicle as upper staging on Blue Streak. Although at present this does not seem a likely requirement, as a similar capability is served by ELDO–A vehicles, a national requirement to launch our own military satellites (*e.g.*, for communications purposes) might depend on this kind of application.

Black Arrow will place a 230 lb satellite into a 310 mile polar orbit from Woomera. Diamant B will send a 396 lb satellite into a low elliptical orbit from French Guiana. These small launchers, operational by 1970, will enable Europe to offer launch services to ESRO and non-affiliated countries as an alternative to purchase of U.S. launch facilities.

It should be recognized that, properly developed, these "national" boosters could fill a gap in European launch capability ranging upwards from the small Black Arrow to the large ELDO launchers. Smaller countries increasingly will be drawn into space research and there could well develop a market for low-cost satellite launchers. At an early stage plans should be made to up-rate Black Arrow and Diamant B. Several options are open in the former case:

(1) Develop existing family of Gamma rocket engines for higher thrust. Develop new terminal stage to exploit full opportunities from increased performance. This could virtually double the payload.

(2) Apply strap-on boosters to raise payload by 40%; a case design is already fully developed in the United Kingdom.

(3) Develop a new Black Arrow second stage exploiting long-standing work by Government and industrial research establishments with liquid hydrogen/liquid oxygen propellents.

This should make possible an extension of present 310-mile orbital capability from 230 lb to something approaching 1 000 lb—closing the gap between the present minimal national launchers and ELDO–A (1 760 lb into a similar orbit). At the same time it would help promote development, in conjunction with France and West Germany, of a new generation of ELDO–B launchers using high-energy propellent top stages necessary to extend European telecommunications facilities in the shape of direct-broadcasting TV satellites in the late 1970's.

The up-rated Black Arrow would have greater utility as a test-bed for electrical propulsion than the present minimum vehicle and would permit further extensions of British research interests (*e.g.*, flight testing of re-entry vehicles).

Conclusion

Europe has within its grasp—on the basis of existing rocket launchers and long-standing propulsion research—the opportunity to create a family of satellite launchers of maximum utility. Low-orbit capability would range from a few hundred pounds of payload (with Black Arrow and Diamant B) to many tons (with development of ELDO–B vehicles). Many of the opportunities stem from a single positive commitment, which should be made now, *i.e.*, a viable European communications satellite programme.

Apart from putting Europe into space communications, it would provide the opportunity to extend many branches of space competence with other types of applications satellites. We should then be in a position to co-operate from strength instead of weakness in major international ventures which increasingly will affect our ability to break into the new markets that the space-related industries are opening up in America and Russia.

A Wallchart Lunarium*

J. R. Millburn†

The phases of the Moon can be demonstrated quite simply and rapidly with the aid of a lamp and a white ball. However, this method lacks permanence. The Wallchart Lunarium (Fig. 1) not only enables the phases as demonstrated to be compared with the changes in appearance of the real Moon, it also enables the difference between the sidereal and synodic periods to be shown, and eclipses to be predicted.

The Lunarium consists of four main parts:

(1) A board, or metal sheet, about 20 in × 30 in, on which is fixed a chart having the days and months marked round the circumference of an 18 in diameter circle.

(2) A disc, slightly smaller than the date circle, free to turn on a fixed pivot at the centre of the date circle. On the surface of this disc is drawn a number of parallel lines representing the Sun's rays, together with a circle representing the Moon's orbit, divided into 29½ parts.

(3) An arm, pivoted at one end in the centre of the disc, and carrying at its other end (at a radius equal to that of the circle representing the Moon's orbit) a white ball representing the Moon. This Moon ball is half covered by a black paper cone, representing the Moon's shadow.

(4) A movable pointer mounted on the central pivot so that it is independent of the Sun's Rays Disc and Moon arm.

In order to demonstrate the phases of the Moon, and its sidereal and synodic periods, the first step is to set the Lunarium to represent the conditions for a *New Moon*. This is done by setting the Sun's Rays Disc so that the diametrical ray (which is marked by a red star) points to the appropriate date, and the Moon arm so that the Moon ball is over the space marked "NEW MOON", *i.e.*, in line with the Earth and Sun. The shadow cone should then be set so that it is parallel to the Sun's rays, pointing away from the Sun. (This cone is held in place by friction at its pivots on the Moon arm.) To mark the position of the Sun at the New Moon, the pointer should be set in line with the Moon arm. The date to which the Sun's Rays Disc is set can be an arbitrary one, but the demonstration is more interesting and useful if the date is that of a recent or forthcoming New Moon.

If the Sun's Rays Disc is now moved forward one day, and the Moon arm is moved so that the Moon ball is over the space marked "1," it will be seen that in order to keep the shadow cone parallel to the Sun's rays it must be rotated slightly, so that a very thin crescent of the sunlit part of the Moon becomes visible from the Earth. Continuing this procedure, it will be found that after 7 or 8 days just one half of the Moon ball will be visible from the Earth—the *first quarter*; and after 15 days, the shadow cone will be pointing directly away from the Earth—the *full Moon*. From this time onwards, the shadow begins to cover the right-hand side of the Moon's face.

After about 27 days it will be found that the Moon arm is once again in line with the pointer. This means that, relative to the stars, the Moon has completed one circuit—hence this time is its *sidereal period*. However, there are still several days to go before the next New Moon, because throughout the past month we have been moving the Sun's Rays Disc slightly each day. In fact, about 29½ days elapse before the Moon is once again in line with the Sun, and this is therefore the Moon's *synodic period*.

To enable the actual appearance of the Moon in the sky to be compared with that predicted by the Lunarium, 29 spaces are provided on a detachable strip of paper at the bottom of the chart, in which the apparent shape of the Moon can be drawn each day.

Fig. 1. Wallchart Lunarium set to show the position of the Moon and its shadow nine days after the New Moon of 14 October.

Of course, the dimensions of the Earth and Moon balls, and of the Moon's orbit, cannot be shown to scale in a model of this size. Consequently, *eclipses* cannot be demonstrated by true shadows. However, if the directions of the nodes of the Moon's orbit are marked on a stationary part of the Lunarium, it can easily be seen whether a particular New or Full Moon will be associated with an eclipse. In the model shown in the figure, the ascending and descending nodes for 1966–71 are marked on a subsidiary dial attached to the central stationary pivot; if the Moon arm is at or near either node at the Full Moon, then an eclipse of the Moon will occur, and similarly if the Moon arm is at a node at the New Moon, there will be an eclipse of the Sun. (The eclipses will not necessarily be visible at a particular place.)

The nodes take about 18 years to move right round the Ecliptic, in the opposite direction to the motion of the Moon itself, so there are two periods each year—a little less than 6 months apart—when eclipses are possible. In 1966, for example, eclipses took place in May and November, and it can be seen from the positions of the nodes on the dial that in 1969 (for example) we may expect to have eclipses in March and September.

* *Based on a model demonstrated at the Autumn Meeting of the British Interplanetary Society (Education Session) on 3 November 1966.*

† *Space Educational Aids Ltd.*

Some Critical Aspects of the ELDO-B Vehicles*

By J. Nouaillet†

As readers of "Spaceflight" know, the ELDO-B programme has not been embarked upon. This article describes the ideas that were put forward for extending ELDO-A performance. It provides an historical account of a subject pertinent to the future of ELDO.

Introduction

The Future Programme Directorate of ELDO, was established by the end of 1963. Its terms of reference were according to the ELDO Convention (Art. 16, para. 3):—

> "*When the Organization comes into existence, it shall continue the study of future possibilities and the need for launchers and ranges. This study shall include experimental research. After a period of two years a report on the study shall be presented to the Council. The Council shall then consider what new programme it would be desirable to undertake and also the orientation of the Initial Programme, having regard to the progress already obtained and the state of the art.*"

A number of studies were very quickly initiated covering the possible improvements of the Initial Programme launcher (ELDO-A) with regard to inertial guidance, apogee system, etc., and the feasibility of a powerful launcher, which would give approximately 250 tons at lift off. This launcher would use a first stage with conventional propulsion (*e.g.*, four RZ-2 engines) with two liquid hydrogen/liquid oxygen upper stages, based upon a unique type of LH_2 engine, which would be used in a clustered pattern for the second stage of the launcher. This launcher was designated ELDO-C. Its development would be preceded by the development of a two-stage vehicle called ELDO-B, for which Blue Streak was proposed as a first stage, the upper stage being more or less identical to what could be an ELDO-C third stage.

During 1964, the studies carried out demonstrated that the above concept was practical, that it could give Europe a capability of 6 to 7 tons in low orbit, which would be quite suitable for manned spaceflight, and an escape payload of about 2 to 3 tons. However, at the end of 1964, during the preparation phase of the first Intergovernmental Conference (held in January 1965), it appeared obvious that the cost of the above programme would certainly exceed the amount which the ELDO Governments would consider and an alternative solution was proposed, to build a three-stage high-energy vehicle by using Blue Streak more or less modified as a first stage with two LH_2/LO_2 upper stages. This programme was put forward before the Government Conference. Two phases were considered for the development of the programme: in the first, a single stage, powered by a single LH_2/LO_2 6-ton thrust engine was put on top of a Blue Streak to obtain the ELDO-B1 launcher; in the second, a second LH_2/LO_2 stage was introduced between Blue Streak and the upper stage and the maximum capability was obtained with this ELDO-B2 three-stage launcher.

Studies of the ELDO-B Programme

In the early months of 1965, a number of studies were put out by the ELDO Secretariat to various companies to examine the critical aspects of the programme:—

Sixth development round of the ELDO-A launch vehicle lifts off at Woomera. In June the first attempt will be made to orbit an 880 lb test-satellite. A viable programme of European communications satellites depends on development of this vehicle in ELDO-B configurations, as explained in this article.
Hawker Siddeley Dynamics

- determination of the upper limit of the mass to be carried by Blue Streak, accepting possible re-inforcement of the vehicle structure;
- general design of the upper stages and examination of the cryogenic problems;
- preliminary project studies of a liquid hydrogen/liquid oxygen 6-ton thrust motor.

In parallel with these studies, the Member States were consulted in April 1965 about the tasks they would wish to undertake within an ELDO-B programme in order to prepare allocation of project studies to companies and firms most likely to be concerned with later actual development. The ELDO Council in July 1965 adopted a division of tasks for project studies which allowed the Secretariat to go ahead and determine the design specifications and the Cost Development Plan of the vehicles. The results of the 1965 studies were available to the ELDO Secretariat between October and December 1965 and by the end of January 1966 most of the Project Studies contracts were placed. These were based on a number of assumptions:—

(1) The programme would be directed towards application satellites mainly in the telecommunications areas: telephone, radio broadcasting, aircraft and ships'

* *Paper presented at the Sixth European Symposium on Space Technology, Brighton, 23–25 May* 1966; *revised for publication July* 1967.

† *European Space Vehicle Launcher Development Organization.*

communications, television broadcasting, etc. For most of these applications, the orbit to be considered was the 24 hr geostationary orbit. This was assuming the existence of an equatorial launching base for operational use of the ELDO vehicles.

(2) The development firings would take place from Woomera, and non-optimized trajectories would be accepted to take into account the possible impact zone restrictions.

(3) The programme would start on 1st January 1967, but some money would be available from May 1966 for experimental studies on the critical parts of the programme.

(4) First orbital firings would take place in 1972 for ELDO-B1 and 1973 for ELDO-B2. The developed launchers would be available to customers from 1974 for ELDO-B1 and 1975 for ELDO-B2.

(5) The aim of ELDO-B1 would be to acquire as quickly as possible technical experience in the cryogenic stage techniques with a very simple vehicle: the payload objective was 350 to 500 kg. in geostationary orbit for a satellite with an apogee motor, requiring neither transfer nor re-light capability. The ELDO-B2 objective would be more ambitious, including a payload capability of 800 to 1100 kg into geostationary orbit, three ignitions of the upper stage engine and a transfer capacity of more than 10 hr between ignitions.

(6) There were strong arguments from the point of view of cost effectiveness, of technical efficiency and of distribution of work, that both phases of the ELDO-B programme should be adopted as a whole even if the phasing of the more advanced ELDO-B2 had to be reworked for financial reasons.

Technical Constraints

The technical constraints put on the programme were:—

(*a*) The Blue Streak vehicle had been chosen from the start as the foundation upon which the programme had to be based for obvious financial reasons; the diameter of the ELDO-B launchers could not practically exceed the Blue Streak diameter, *i.e.*, 3·05 m. This figure is suitable for the ELDO-B1, but too low for the ELDO-B2. From a purely technical point of view, a redesign of the first stage would have been preferable.

(*b*) A number of years ago, work was initiated within a French national programme to design and build a 6-ton liquid hydrogen/liquid oxygen motor with one turbo-pump assembly and four 1·5-ton thrust chambers. One of the prerequisites, when allocating a large share of the motor work to France, was that the same turbo-pump assembly should be used. Although later improvements could be expected to increase the thrust which this turbo-pump assembly could afford, this put a slight constraint on the programme.

(*c*) The distribution of tasks between Member States as a function of financial contributions as well as of technical expertise is something which is far more difficult to accept from the viewpoint of maximum technical efficiency, but this is part of an international programme procedure, and is more or less stated in the ELDO convention (Art. 2, para. 4):

"*The Organization shall seek to promote the co-ordinated development of techniques relevant to its activity in the Member States and shall assist Member States, on request, to make use of the techniques used or developed in the course of its work.*"

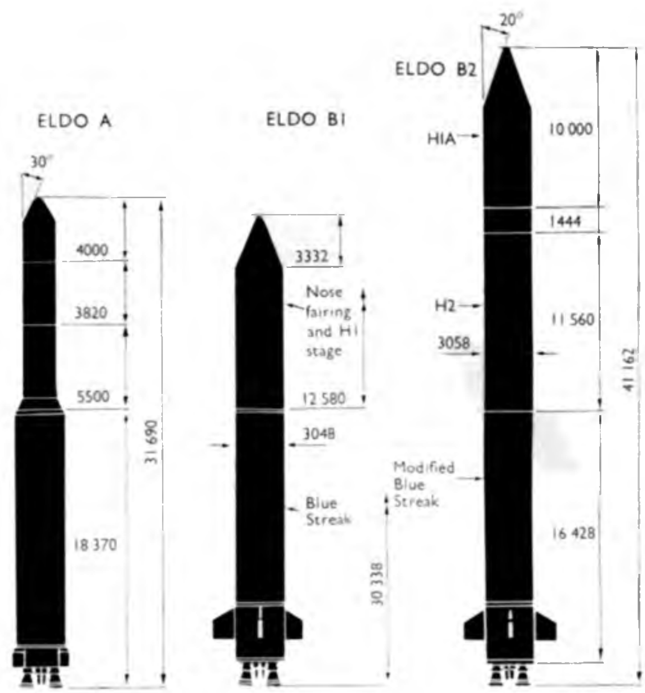


Fig. 1.

TABLE I: *Main Parameters of the ELDO-B Vehicles*

	ELDO-B1	ELDO-B2
First Stage	*Blue Streak*	*Modified Blue Streak*
1. Mass at burn-out (tons)	7·25	8·10
2. Burnt propellent mass (tons) ..	86·20	84·20 to 86·20
3. Specific impulse:		
ground (lb sec/lb)	248·75	248·75
vacuum (lb sec/lb)..	285·75	285·75
4. Thrust at lift off (tons) (2 engines)..	136·1	149·7
Second Stage	*H1*	*H2*
1. Mass at burn-out (tons)	1·0	2·0
2. Burnt propellent mass (tons) ..	7·5	17·0
3. Specific impulse (lb sec/lb) vacuum	425	425
4. Thrust (tons)	6·0	24·0
Third Stage		*H1A*
1. Mass at burn-out (tons)		1·15
2. Burnt propellent mass (tons) ..		7·50
3. Specific impulse (lb sec/lb)		425
4. Thrust (tons)		6

Mass Break-down at Lift-off (tons)			
First stage	93·45	92·30	94·30
Second stage	8·50	19·00	10·00
Third stage	0·00	8·65	8·65
Nose cone fairings	1·05	1·05	1·05
Payload (maximum)	3·00	4·00	2·00
Total	106·00	125·00	125·00

General Technical Characteristics

Fig. 1 shows the general dimensions of ELDO-A, B1 and B2. It is noticed that:

(i) ELDO-A and ELDO-B1 are of the same order of magnitude with an overall mass of 104 to 107 tons.

(ii) ELDO-B2 is quite long and thin, and some proposals have been put out to try to reduce this length by increasing the diameter of the second stage. We are not, at present, sufficiently aware of all the problems involved to accept such a revolutionary design.

The following nomenclature has been adopted within the ELDO-B project studies. The ELDO-B1 second stage is called H1, the ELDO-B2 second stage H2 and the ELDO-B2 third stage, directly derived from the H1 stage, is called H1A. We call Blue Streak the first stage in both cases, adding that it is a modified Blue Streak for ELDO-B2.

Table I gives a breakdown of the masses of the different configurations of the ELDO-B launcher. The masses of propellents in each stage have been determined through optimization studies carried out in parallel with R.A.E., Farnborough, and Germany on the ELDO-B2 vehicle.

The propellent mass obtained for the H1A stage is not really the optimum one for an ELDO-B1 vehicle (Stage H1). Adopting the same propellent mass for H1A results in a loss of about 10% of the payload capability of the ELDO-B1 launcher, but a large reduction in development and manufacture cost.

A safe value of 6 tons has been chosen for the thrust of the basic propulsion unit; an increase of this figure to 7 tons would result in a slight increase of the payload in geostationary orbit, and we have made provision in the engine design to allow this extension later on. Clusters of four and five engines have been considered for the H2 stage during the optimization study. It has been thought that the small advantage in performance of a five-engine cluster was not worth the problems to be solved for a fifth central engine (attachment, equalization of propellent flows, access, etc.), and it was felt that a better way of improving performance would be to achieve, later on, a higher thrust if the motor development was really successful.

The nominal curves derived from the optimization studies are shown in Fig. 2. The payloads obtained covered a large range of applications:—

- heavy telecommunications satellites and radio broadcast satellites with ELDO-B1;
- useful experiments on television diffusion with ELDO-B1;
- television diffusion to collective cheap antennae with ELDO-B2 and even direct diffusion to domestic receivers if some improvements appear possible in the 1975–80 period either on power-supply technology, or on launcher capability (*i.e.*, the addition of solid boosters on ELDO-B2 as proposed by Mr. Dorleac at the 1965 I.A.F. Congress in Athens).

We expected that these figures, and these capabilities, would appear attractive to the ELDO Governments, although it was quite difficult for us to choose objectives for a launcher programme without any guidelines from the Governments on possible space programmes. We were trying to determine a launcher programme without knowing what requirements we had to meet and how much money the possible mandators would be ready to pay for.

Technical Options Already Made

Most of our work has been directed to the vehicle definition. The first stage of the ELDO-B launchers, namely the variants of the Blue Streak vehicle needed for the ELDO-B programme, was one of the critical problems, and the following modifications were identified:—

- to carry an overall mass of 30 tons on top of Blue Streak a significant increase of the internal pressure of the tanks is needed and the skin thickness (0·6 mm in the basic Blue Streak) would then be increased to 1·5 mm. The dry mass of the vehicle becomes 0·85 tons higher;
- to improve stability it was decided that fins should be added at the base of the vehicle, notwithstanding redesign of some parts of the control system necessary to cope with a lower overall bending frequency and a low lift-off acceleration of 1·2 *g*;
- to meet the requirements of the integrated telemetry and checkout system envisaged, some modifications of the instrumentation of the stage are necessary;
- to allow an overall mass of 125 tons at lift off, a thrust increase in the engines is necessary. Following a Rolls-Royce proposal, a propulsion unit of 165 000 lb thrust was chosen. To get this thrust with a safe engine, development of a modified thrust-chamber is necessary as well as some redesign of the turbo-pump assembly.

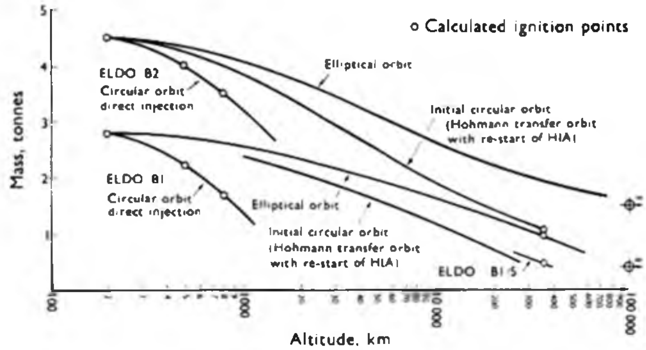


Fig. 2. Estimated nominal performance of ELDO B1 and B2 launch vehicles (May 1966).

In fact, the B2 first stage, keeping the basic Blue Streak system, implies a good deal of new development work. Within the ELDO-B1 phase of the programme, leading to the ELDO-B2 vehicle, the following modifications were planned:

- addition of fins and improvement of the control system;
- evolutionary modification of the telemetry and checkout system;
- modification of the turbo-pump assembly of the RZ-2 engines, to get a safer margin even at 150 000 lb thrust.

The second critical problem to be looked at was the liquid hydrogen/liquid oxygen propulsion unit. This was one of the most critical tasks of the programme from the point of new techniques and timescale. This engine (Fig. 3) had the following main characteristics:—

- thrust 6 tons;
- mixture ratio 5·35 $\pm$ 0·5;
- chamber pressure 30 to 31 Kg/cm²;
- turbo-pump driven by a separated gas generator capable of three ignitions;
- regenerative cooling of the chamber, the extended part of the nozzle being film and radiation cooled.

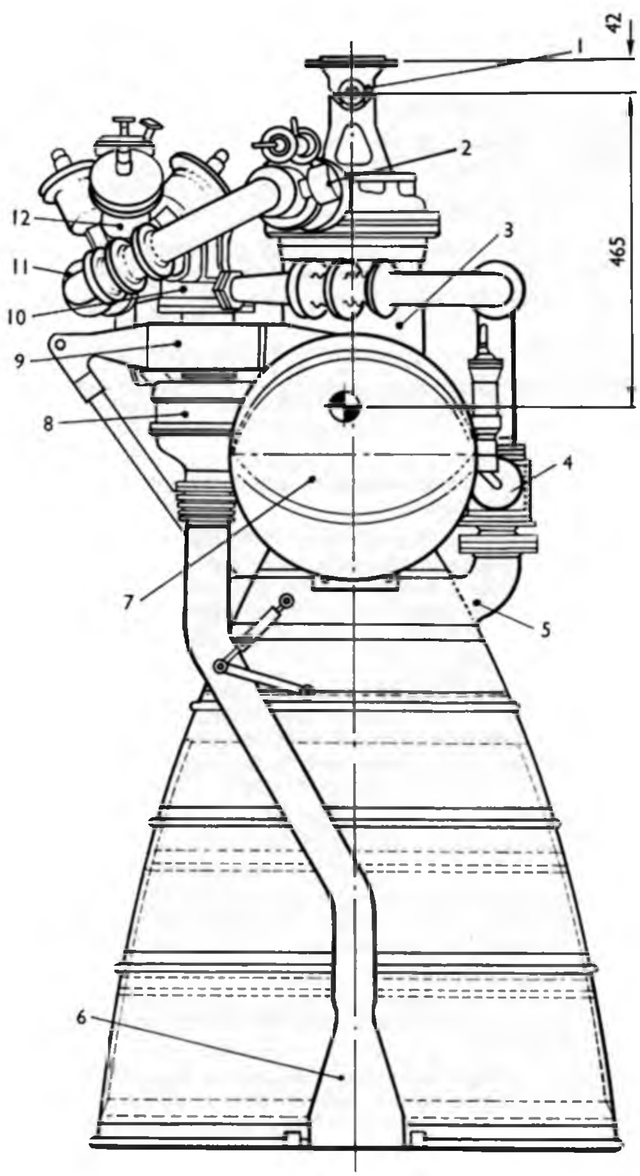


Fig. 3. Hydrogen fuelled rocket engine for ELDO B launcher.

Key: 1. Gimbal; 2. Oxygen injector; 3. Combustion chamber; 4. Hydrogen injector valve; 5. Hydrogen manifold for regenerative cooling; 6. Turbine exhaust; 7. Reduction unit cooling bottle, containing gaseous hydrogen; 8. Turbine; 9. Reduction unit; 10. Hydrogen pump; 11. Oxygen pump outlet; 12. Solid-propellent gas generator.

The turbo-pump assembly was to be derived from the one which was under actual development through a French national programme. The design of the H1/H1A stage has been the subject of very hard discussions. The basic problems to be solved were:—

how to put high quality insulation on this stage;

how to avoid this insulation being damaged during the transfer through the atmosphere;

how to get rid of the heat accumulated in the structure during the transfer through the atmosphere.

Two concepts of this liquid hydrogen stage had been retained for comparison purposes at the end of the feasibility studies (Fig. 4). The first one, called the "I" solution, puts a light efficient insulation on the stage and protects it by extending the nosecone fairing of the vehicle down to the bottom of the cryogenic stage, which is carrying the payload on an integrated structure with a common bulkhead between the LH_2 and LO_2 tanks. Two technical difficulties can be predicted: (i) the jettisoning of a very long and heavy fairing without any contact with cryogenic tanks, and (ii) the design and insulation of a common bulkhead. The second possible solution, called the "S" solution, had two completely separated cryogenic tanks, hanging within a conventional structure, support the nosecone fairing as well as the payload. A careful comparison of the two solutions led to the conclusion that:—

(*a*) a 10% performance gain may be expected from solution "I" in geostationary orbit;

(*b*) no significant difference is foreseen in timescale and development cost;

(*c*) the technical problem to be solved in developing solution "S" may appear to be simpler, but those involved in solution "I" are better known.

Since a major consideration in the choice of the stage configuration must be the performance, and since the solution "I" is not significantly inferior in any other area, solution "I" was selected for the remainder of the project studies.

The definition of the H2 stage has not been so well advanced. The main technical choices still under discussion are:—

the material to be used;

a pressure stabilized type of structure compared with a self sustaining structure. Reinforcement of the structure is needed to get a sufficient stiffness for the ELDO-B2 launcher and the comparison between the two systems is quite relevant;

the pressurization system to be adopted.

Control would be achieved by swivelling the engines. The difference between the engines for the H1 and H2 stage could probably be very small.

The choice of the "I" solution put a heavy stress on the nosecone fairing design (Fig. 5). After some studies, the main dimensions were chosen as shown in this figure, taking into account:—

a reasonable volume for the satellites;

consistency with the manufacturing facilities existing for the Initial Programme of ELDO;

a certain margin of safety for the heat transfer and the structural performance.

Separation has to occur at approximately 1 *g* in the ELDO-B2 vehicle, after ignition of the H2 stage. Two possibilities exist:—

parallel separation, the two halves of the fairings being pushed aside by pyrotechnical actuators;

rotating separation each half fairing rotating around an axis situated in the strong ring of the H1 stage.

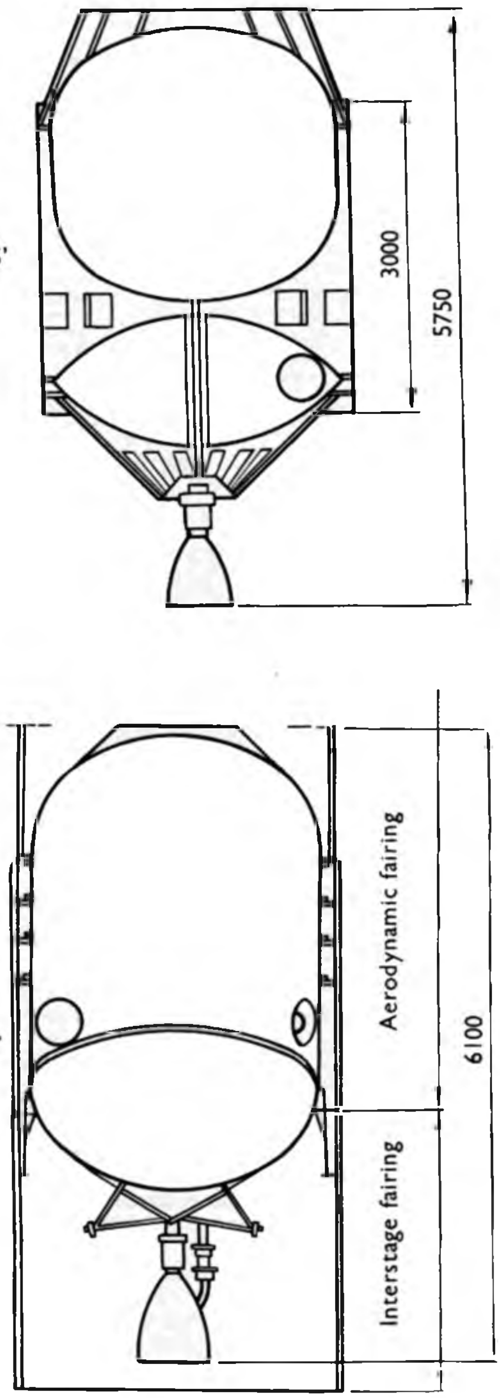


Fig. 4. ELDO-B stage configurations.

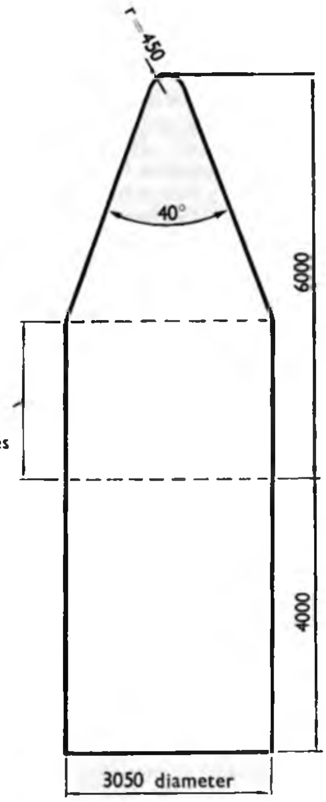


Fig. 5. Aerodynamic nosecone for ELDO-B launcher.

No test satellite programme has been defined for the ELDO-B programme. It was felt that within a European Space Programme, a useful satellite programme fitted to the ELDO-B development programme could be established, including either development of specific technological satellites, or even application satellite prototypes. The objectives of a European Space Programme should nevertheless be better delineated.

Conclusion

If the ELDO-B programme could be more firmly aligned with an agreed policy and definite technical objectives for European space activity, such a programme, based upon the completion of the ELDO Initial Programme, could give Europe in the 1975–85 period a worthwhile capability in space and valuable experience in advanced technology.

The cost of the programme would not be likely to exceed a peak expenditure of 80 to 85 million dollars per year in the 1969 to 1974 period, provided the critical areas of the development programme were properly funded up to 1969, at a much lower level; the overall cost up to 1975 is evaluated roughly at 600 million dollars to be divided between six or seven Member States.* In order to utilize to the full the potential which exists in Europe we must adopt more ambitious aims and start something which really is a Future Programme.

---

* All figures are given in relation to economic conditions existing at the beginning of 1966. They do not include any provision for contingency.

Thermal Design and Testing of the ESRO II Solar Astronomy Satellite*

By P. Brunt† and P. J. Conchie†

The ESRO II satellite is the first of a series of satellites to be launched as part of a co-operative programme between the National Aeronautics and Space Administration and the European Space Research Organization. During the launch on 29 May 1967 by a Scout rocket from the Western Test Range at Point Arguello, California, the fourth stage failed to ignite and the satellite burnt up on re-entry. A back-up satellite is to be launched in April 1968. The satellite will measure the energy levels and spectral distribution of solar and cosmic radiation for a period of one year during the solar maximum. For this purpose, it will carry seven experiments designed and developed by research groups in Europe.

1. Orbit Characteristics

As the purpose of ESRO II is the measurement of radiation emitted by the Sun, the prime requirement is for the satellite to remain continuously in sunlight. Any periods spent in darkness will result in lost information for the majority of the experimenters, particularly as some of them are monitoring short term effects such as solar flares. This dictates that the orbit plane should ideally be perpendicular to the solar vector. A diagrammatic representation of the orbit is shown in Fig. 1. It is also a requirement to investigate radiation levels at altitudes which vary from the outer fringe of the Earth's atmosphere up to the base of the Van Allen belts. The lower limit is set by the lifetime requirement of one year. An orbit has, therefore, been chosen that is slightly elliptical, the perigee being at 350 km and the apogee at 1100 km. This orbit, even with the possible injection errors of the Scout vehicle, ensures that the life of the satellite will be in excess of one year.

To maintain the orbit plane perpendicular to the solar vector throughout the year, the inclination of the orbit is retrograde at 98·22°. Thus, the orbit plane rotates about the Earth at the same rate as the Sun and the satellite will be continuously in sunlight. Of course, injection and launch time errors, etc., can result in the satellite passing into periods of shadow and the satellite has been designed to operate satisfactorily in conditions of maximum shadow which can be up to 37 min of the 99 min orbital period (Fig. 4).

So that injection takes place when the orbit plane is perpendicular to the solar vector, the launch time must be controlled and for any particular point on the Earth's surface, the optimum launch conditions occur only twice per year. In 1967 at the Western Test Range, these occur on 1 March and September. Delay in the launch date means that the satellite will enter shadowed orbits earlier in the year and will spend a larger percentage of the year in shadowed orbits.

Certain experiments require to sample, alternately, radiation from the Sun and background radiation from space. It is, therefore, convenient to achieve this requirement by providing a spinning satellite with the spin axis perpendicular to the "Sun line" and the experiments viewing radially perpendicular to the spin axis. A viewing accuracy of $\pm 10^\circ$ is required and it is, therefore, necessary to provide an attitude control system to maintain the spin axis perpendicular to the sun line to within this tolerance.

Errors in launch time, launch date and injection conditions will also affect the initial attitude of the satellite spin axis relative to the solar aspect line. The most likely sources of error have been examined and it is estimated that the maximum initial attitude error will not exceed 40°. The control system provided is capable of removing such initial errors and subsequently maintaining the spin axis attitude to the required accuracy.

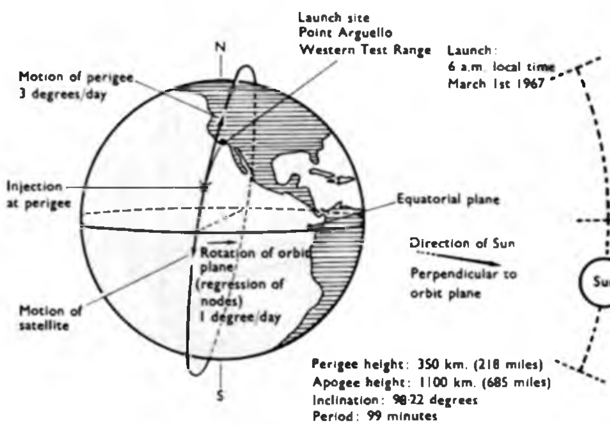


Fig. 1. ESRO II initial orbit.

Some of the experiments also require that the sensors traverse the solar disc at a specific rate. This, therefore, dictates that a spin rate control system be employed, initially to de-spin the satellite from the initial high spin rate injection conditions and, subsequently, to maintain the spin rate throughout the one year lifetime of the satellite between the limits 15 and 40 rpm.

2. Satellite Configuration

The overall configuration of the satellite was determined by a number of considerations, the more important of which may be summarized as follows:—

(*a*) Viewing requirements for the experiment sensors.
(*b*) Launch vehicle heat shield volume constraints.
(*c*) Spin stabilization of the satellite.
(*d*) Structure to accommodate launch thrust loads.
(*e*) Mounting of internal equipment and access thereto.
(*f*) Power system solar cell area requirements.

The viewing requirements of the seven experiments have been met by providing essentially three areas of sensor location, one at each end of the cylinder and a central band around the satellite mid-length.

The satellite is mounted on the Scout fourth stage via the base of a central thrust tube. The thrust tube carries two honeycomb floors midway along it, on which the electronic equipment and four of the experiments are mounted. Two experiments are mounted at the upper and lower ends of the tube and one experiment to the outside of the upper tube. Fig. 2 and 3 show the structure and experiment layout.

Since the satellite spins with its axis nominally perpendicular to the solar vector, the maximum solar cell area for a given area and hence, weight, is obtained by mounting the cells in the form of a cylinder around the periphery. The cells are bonded into fibreglass insulation which is in turn bonded to aluminium honeycomb panels. Each panel comprises two facets of a 12-sided figure and the panels are carried on six extruded magnesium alloy longerons, bolted to the floors and stabilized at each end cover position by frames. A technical description of the satellite has been given by Hume.[1]

* *Presented at the Spring Meeting of the British Interplanetary Society at Loughborough University of Technology, April* 1967.

† *Hawker Siddeley Dynamics Ltd., Stevenage, Herts, England.*

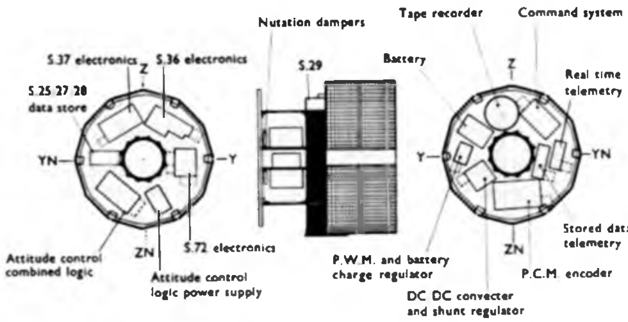


Fig. 2. Layout of basic structure.

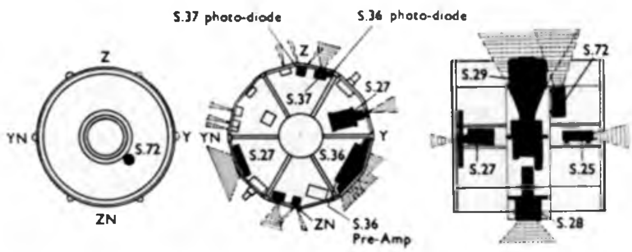


Fig. 3. Installation of experiments.

3. Thermal Design Concept

The most important considerations influencing the thermal design may be summarized, therefore, as follows:—

The satellite will spend the larger proportion of its one year in space in a full Sun orbit but the design must ensure that temperatures remain acceptable should shadowing of up to 37% of each orbit take place.

The solar cells are mounted on the body of the satellite, which is basically a spinning cylinder with its spin axis maintained perpendicular to the solar vector.

In addition, ESRO stipulated that a passive thermal control system should be used. This means that acceptable temperatures must be achieved by applying coatings with suitable solar absorptance and emittance values to the outer and inner surfaces. Devices which give variable absorptance and/or emittance values (*e.g.*, louvres, maltese crosses), and electrical heaters, could not be used.

The area available for temperature control on the outer surface is small, since over 80% of the area is covered by solar cells. Since the end covers are never illuminated by the Sun (except, possibly, for a short period on injection into orbit) they can be used to adjust the internal temperature to a suitable value by coating their outer surfaces with a material that will give an appropriate emittance. These end covers are thin, aluminium alloy discs which serve as a substrate for the thermal control coatings and are designed not to carry any load.

The two experiments mounted in the thrust tube, S29 and S28, will receive no direct solar radiation and would clearly run at unacceptably low temperatures unless the rate at which they radiate heat to space were reduced by means of suitable insulation. The type of insulation envisaged was a blanket consisting of ten layers of aluminized Melinex with the eight inner layers crumpled and partially straightened to reduce contact between layers to a minimum.

Consideration was given to the technique of reducing temperature fluctuations within the satellite in shadowed orbits by radiatively de-coupling the solar cells from the internal compartment by insulating the back of the solar cell panels using multilayer blankets as described above.

The internal structure and equipment required protection against corrosion and for this purpose a white epoxy paint was proposed. This had the advantage of giving a high emittance for the internal compartment as well as making it easier to see when working inside the satellite; for example, a dropped nut would be easily seen against the white of the floor.

4. Detail Thermal Design

After the broad concept of the thermal design had been fixed, a detailed theoretical study was begun with the object of stipulating the surface treatments to be applied to the satellite in order to obtain acceptable satellite temperatures throughout the orbit lifetime.

The temperature of any part of a spacecraft depends on a number of factors listed as follows:—

(*a*) The rate at which solar radiation, Earth albedo and Earth re-radiated energy are absorbed by the spacecraft.

(*b*) The rate at which heat is being radiated to space by the spacecraft.

(*c*) Power dissipation within the satellite.

(*d*) Conductive heat interchange between the various parts of the satellite.

(*e*) Radiative heat interchange between the various parts of the satellite.

(*f*) Heat received by the satellite from the rocket fairing during launch.

(*g*) Kinetic heating of the satellite in the upper atmosphere after fairing ejection.

(*h*) If the temperature is changing, the time rate of change of temperature also depends on the thermal capacity of the part of the satellite being considered.

Items (*f*) and (*g*) are usually reduced by judicious design of the launch vehicle by application of an ablative coating to the external surface of the fairing, if necessary, and by ejecting the fairing at a sufficient height to minimize kinetic heating. This may reduce the weight available for payload and this factor must be considered in the satellite weight breakdown.

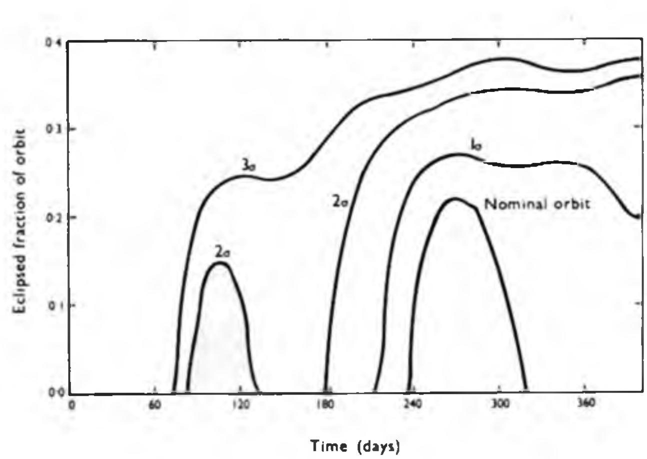


Fig. 4. ESRO II eclipse fractions. Mean orbit and worst combination of errors at 1, 2 and 3-sigma levels.

5. Mathematical Model

The satellite was now considered as consisting of a number of isothermal nodes and for this purpose some simplifying assumptions were made. To reduce the number of nodes, and hence the amount of computer time which would be needed during the calculation phase, the satellite was considered as being made up of six identical "slices," each "slice" lying between a pair of longerons.

The floor mounted equipment was lumped together into an annular ring, one on each floor, and each ring was given the same total volume, power dissipation and thermal capacity as the sum of the constituent units mounted on that floor. Fig. 5 depicts the final ESRO II model which consisted of 36 nodes.

For each node, an expression may be written equating the rate at which heat enters the node to the rate at which heat leaves the node:

$$m_i C_{pi} \frac{dT_i}{dt} = \alpha_i(qs_i + qa_i) + \epsilon_i qe_i - \sigma\epsilon_i F_{spi} A_i T_i^4 + \sum_{j=1}^{N} K_{ji}(T_j - T_i) + \sum_{j=1}^{N} \sigma\,\epsilon_{ij} g_{ij}(T_j^4 - T_i^4) + P_i + q_{fi} + q_{mol\,i}$$

Notation:

A	area radiating to space	cm^2
mC_p	thermal capacity	cal/°C
F	view factor	
g	geometric flux	cm^2
K	thermal conductance	cal/sec°C
N	total number of nodes	
P	power dissipation	cal/sec
qs	solar flux incident on the node	cal/sec
qa	albedo flux incident on the node	cal/sec
qe	Earthshine incident on the node	cal/sec
α	absorptance to solar and albedo flux	
ϵ	infra-red emittance	
σ	Stefan-Boltzmann constant	$cal/cm^2\ sec°K^4$
T	temperature	°K

Subscripts:

i, j	nodes i and j ranging from 1 to N
sp	space
f	fairing
mol	molecular heating

To ease manipulation let

$$D_i = \alpha_i(qs_i + qa_i) + \epsilon_i qe_i + \sum_{j=1}^{N} K_{ji}(T_j - T_i) + P_i + q_{fi} + q_{mol\,i}$$

$$B_{spi} = A_i F_{spi}\,\sigma\,\epsilon_i$$

$$B_{ij} = \sigma\,\epsilon_{ij} g_{ij}$$

Then

$$m_i C_{pi} \frac{dT_i}{dt} = D_i - \left(B_{spi} + \sum_{j=1}^{N} B_{ij}\right) T_i^4 + \sum_{j=1}^{N} B_{ij} T_j^4$$

Consequently, the temperature derivatives of the complete set may be expressed as:

$$\begin{vmatrix} -(B_{sp1} + B_{12} + \cdots + B_{1N}) & B_{12} \cdots B_{1N} \\ B_{21} & -(B_{21} + B_{sp2} + \cdots + B_{2N}) \cdots B_{2N} \\ \vdots & \vdots \\ B_{N1} & B_{N2} \cdots -(B_{N1} + B_{N2} + \cdots + B_{spN}) \end{vmatrix} \begin{bmatrix} T_1^4 \\ T_2^4 \\ \vdots \\ T_N^4 \end{bmatrix} = \begin{vmatrix} m_1 C_{p1}\dot{T}_1 - D_1 \\ m_2 C_{p2}\dot{T}_2 - D_2 \\ \vdots \\ m_N C_{pN}\dot{T}_N - D_N \end{vmatrix}$$

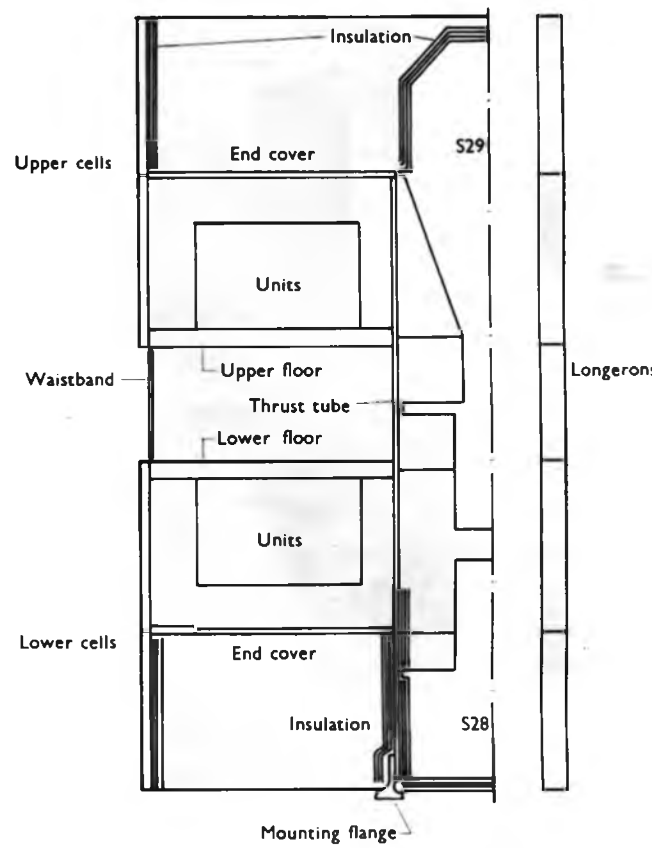


Fig. 5. Mathematical thermal model of the ESRO II satellite.

For calculation of transient temperature histories the above temperature derivatives are integrated numerically. If only the steady state temperatures are required, *i.e.*, the derivatives are zero, then the foregoing set of equations can be solved as a set of simultaneous equations: $B(T^4) + D = O$. The set of equations is generally referred to as the *Mathematical Model.*

6. Solar, Albedo and Earthshine Flux Values

The output of energy from the Sun is constant over the range of the spectrum which influences the satellite temperature. However, since the Earth's orbit round the Sun is elliptical, the distance of the satellite from the Sun, and hence the energy falling on the satellite in unit time, varies throughout the year. The solar constant was taken as being 1396 w/m^2, varying by $\pm$ 3·4% over the year.

The values of albedo and earthshine vary considerably over the surface of the Earth but the average value of each for the whole orbit varies little throughout the year. The values taken for these average fluxes were an albedo of 0·35 times solar flux at the subsolar point, and an earthshine of 250 w/m^2.

In examining the effect of variations in albedo and earthshine, the albedo was considered to vary by $\pm 15\%$ and earthshine to vary between 140 w/m^2 and 320 w/m^2.

7. Cases Considered by the Mathematical Model

Since the satellite will, ideally, spend a large percentage of its orbit life in a full Sun orbit, the early development of the mathematical model was carried out for such an orbit assuming average solar, albedo and earthshine fluxes.

The variables in the mathematical model at this stage were the surface characteristics of the longerons, waistbands, end covers and solar cell panel back faces. A number of computer runs were performed to establish the effect of varying these characteristics. During these early runs published values were used for solar cells, paints, etc., while conductances between nodes contained uncertainty factors until the results of tests to measure all these values could be incorporated in the model. Then it would be possible to calculate spacecraft temperatures for a full sun orbit with maximum inputs—*i.e.*, Earth and satellite at closest to the Sun, maximum albedo/earthshine combination and 5% tolerance on surface characteristics.

This gives the maximum temperatures that it is possible to achieve in orbit and for the floor mounted equipment the maximum temperature was established at 30° C by suitable choice of the end cover emittances.

A check on the lowest temperatures to be expected could then be carried out by considering the satellite in a 37% shadowed orbit with the Earth at its furthest point from the Sun, the minimum albedo/earthshine combination and a 5% tolerance in the reverse sense on surface characteristics.

Other cases to be considered would be the injection case with satellite inclined towards (or away from) the Sun, the boost phase and the economy mode in which a certain amount of the equipment in the satellite would be switched off to allow the battery to re-charge.

8. Detail Test Programme

As soon as the satellite has been divided into nodes, for which the mathematical model will then be used to calculate temperatures, consideration can be given to the detail test programme. This consists, broadly, of the measurement of three parameters followed by tests to demonstrate that materials chosen for their thermal characteristics also have the mechanical and other qualities to survive the environment (Fig. 6).

8.1. *Thermal Evaluation*

The three parameters which need to be measured so that values may be included in the mathematical model are:

(i) Conductance.

(ii) Absorptance to solar radiation.

(iii) Emittance at satellite temperatures.

8.1.1. *Conductance.* Conductance is quite simply the rate at which heat is conducted across, say, a joint when a unit difference in temperature exists on either side of the joint.

On the ESRO II project, a programme was carried out to obtain a number of typical conductances for contacting faces, with and without joint interface fillers, the information being used to evaluate the conductance for equipment boxes mounted on the floors. In addition, measurements were made of conductances for representative joints and attachments such as the floor-to-thrust tube bolted joint and the attachment of a solar cell panel to a longeron. The insulation performance of the multilayer Melinex blankets was assessed by measuring heat flow and temperature drop across them and the result expressed as an effective conductance.

In retrospect, it is appreciated that more could have been done to reduce errors in the test methods but the order of accuracy obtained was undoubtedly sufficient for a satellite of the ESRO II type.

8.1.2. *Absorptance to Solar Radiation.* Absorptance measurements were performed by the Space Department of R.A.E. Farnborough on a Beckman DK2A Spectrophotometer with an integrating sphere attachment. A small sample of each test surface was placed, in turn, in the sphere and a monochromatic beam passed alternately onto the sample and the reference port of the integrating sphere by means of an oscillating mirror.

The integrating sphere has walls which are good diffuse reflectors thus ensuring that the walls will assume a uniform brightness dependent on the energy of the beam entering the sphere.

The beam is incident alternately on a standard and a sample which are suitably placed on the sphere walls. The average sphere wall brightness is measured in both cases, the ratio of the two signals being a measure of the absolute hemispherical spectral reflectance at a particular angle of incidence. The signal is passed to the recorder pen which is deflected by an amount proportional to the ratios of the sample-to-reference signals. The procedure is repeated for a range of wavelengths from about 320 to 2300 millimicrons.

The effect of UV and corpuscular irradiation on absorptance was also determined. In the case of the UV, the sample was exposed to a simulated 4 Sun months of irradiation, absorptance being measured before and after irradiation. Specimens used to determine the effect of particle radiation on absorptance were subjected to 1×10^{14} 4 MeV electrons/cm^2.

In general, the UV and particle irradiation caused some increase in absorptance which varied according to the test surface. The UV had little effect on the solar cells while the effect of particle irradiation was more marked, increasing absorptance by about 4%.

8.1.3. *Emittance.* The method of emittance testing was to suspend a copper plate with its faces covered with the test surface—paint, Melinex, solar cells, etc.—in a liquid nitrogen cooled chamber. The specimen was illuminated by means of a carbon arc or mercury-xenon lamp to raise its temperature to about 70° C. The lamp was then switched off and a cooling curve of temperature against time plotted for the sample via a thermocouple embedded in the plate. To obtain the emittance it was necessary to measure the slope of the cooling curve and to know the thermal capacity of the specimen. Errors were also introduced since, although the plate edges were polished, some heat loss took place from them and this would be significant when testing low emittance samples.

The results of these tests were, in general, disappointing. Future measurements will use a plate containing a heater within it and the power dissipation required to maintain a number of steady temperature values will be measured.

8.2. *Material Evaluation*

Besides the conductance, absorptance and emittance tests described above, it was necessary to demonstrate that the materials used to achieve the required thermal characteristics were suitable for use in the pre-launch, boost and orbit environments. Some examples of the features which were examined are as follows.

8.2.1. *Pre-Launch Phase.* Besides giving a known value of emittance, paints used on the structure had to be capable of protecting the substrate from corrosion especially since a large proportion of the structure was magnesium alloy. The painting process had to ensure that the correct pretreatment was used so that good adhesion of the paint was obtained.

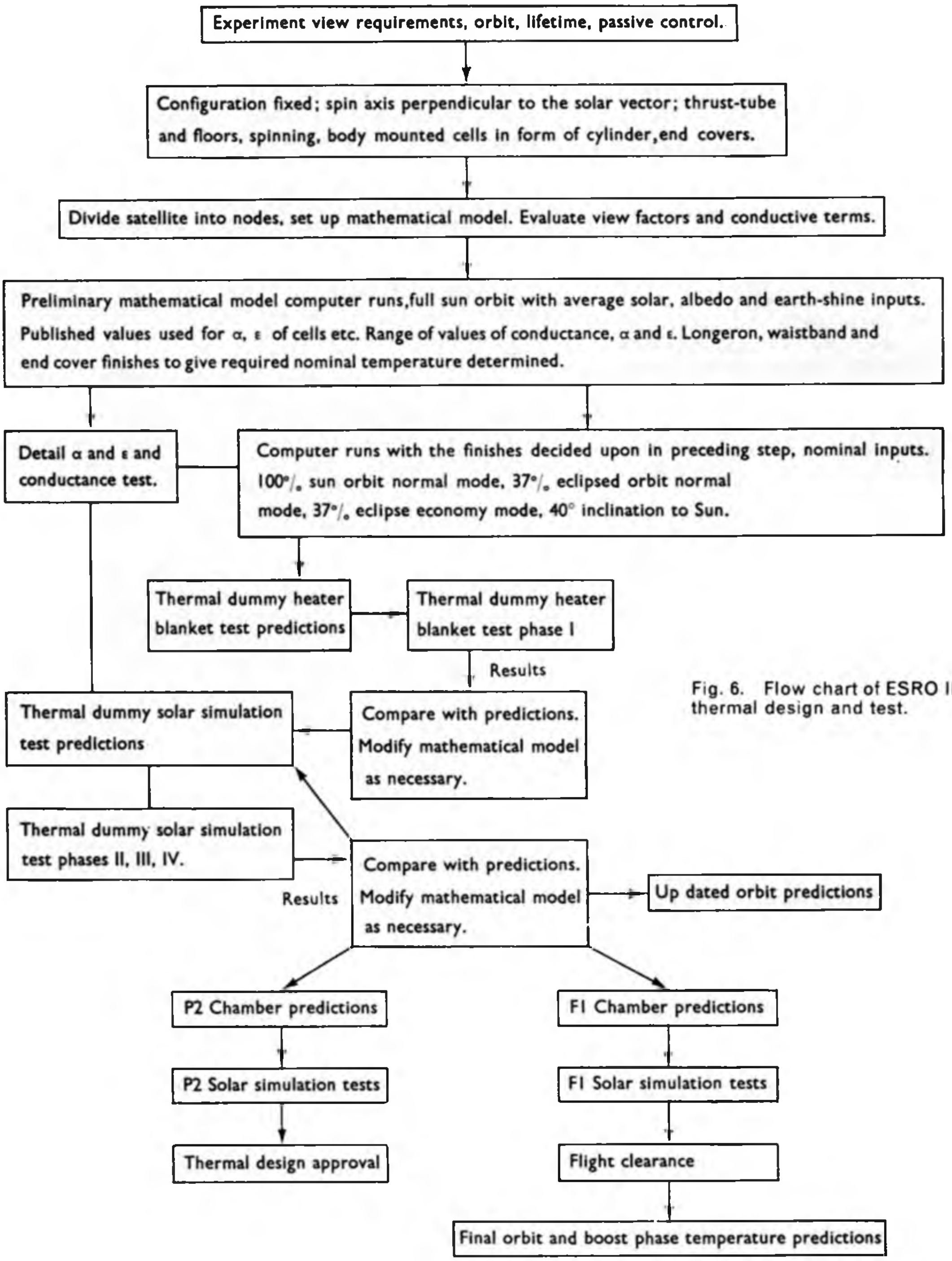


Fig. 6. Flow chart of ESRO II thermal design and test.

8.2.2. *Boost Phase*. Again, the paint finishes had to be able to withstand launch vibration especially on items which were subject to considerable movement such as the end covers.

The design of the blankets took into account the fact that sufficient gaps were necessary around the edge to allow rapid venting of the air contained between the layers. The layers are ultrasonically welded around the edge and a rapid depressurization test of a blanket showed the necessity of leaving more vent area than that allowed in the original design. The half inch of weld—half inch gap had to be changed to a half inch of weld—one inch gap to eliminate excessive ballooning of the blanket.

8.2.3. *Orbit Phase*. The orbit environment is, in many ways, the more severe of the three. Thermal cycling of painted surfaces is the most rapid way of discovering shortcomings in adhesive capabilities of the paint.

Darkening of some materials such as the Melinex insulation material, solar cell cover glass adhesive and white paints due to UV radiation, bleaching of the black paint used on the longerons and waistbands, and outgassing rates of the paints and silicone grease, were all examined.

9. Full Size Satellite Tests

Full size satellite thermal testing falls into two main categories:—

(*a*) Thermal vacuum tests.

(*b*) Solar simulation tests.

9.1. *Thermal Vacuum Tests*

The ESRO II thermal vacuum tests were carried out in the Hawker Siddeley Dynamics facility at Stevenage on the P2, F1 and F2 satellites. In the prototype tests, the satellite was operated as it would be in orbit while its temperature was maintained for several days at 35° C and − 15° C alternately. Checkouts of the experiments and on-board systems were made at frequent intervals to prove their ability to operate satisfactorily at temperature extremes and to pin-point and rectify any detail failures.

Similar tests were carried out for the flight satellites except that the temperature extremes were − 10° C and 25° C, the temperature range within which the satellite internal package is expected to operate in orbit.

Additional thermal vacuum tests were performed on F1 in the TRW Systems 30 ft diameter solar simulation facility at Redondo Beach, California, in January of this year. It is possible in this facility to vary the distance of the spacecraft from the lamps so that hot and cold cycles can be carried out by moving the satellite to a suitable point in its travel range. This method of thermal vacuum testing, which is common in the United States, has the advantage that the relative values of temperature at different points in the satellites are similar to those obtained in orbit whereas temperatures are the same at all points for a chamber with a uniform temperature shroud. The main disadvantage is the higher operating cost of the chamber for the solar simulation method.

9.2. *Solar Simulation Tests*

The cost of the design, manufacture and launch of a satellite is such as to make it vital to obtain a high degree of confidence in the ability of the developed mathematical model to predict orbit temperatures to an acceptable level of accuracy. Tests are, therefore, carried out on a thermally representative full size spacecraft in a solar simulation chamber, and a comparison made between measured and predicted temperatures. If the model is proved capable of predicting the temperatures obtained in the chamber, one can feel confident in its ability to incorporate the additional effects of albedo and earthshine correctly.

9.2.1. *Thermal Dummy Tests.* Because of the late stage in the development programme at which a prototype satellite would be available for solar simulation testing, a representative thermal dummy was made. The structure was to the proposed flight standard but the experiments, electronics, battery, tape recorder, etc., were replaced by dummy units, closely similar to the real units in power dissipation, physical size, thermal capacity, method of mounting and surface finish.

The testing of the ESRO II thermal dummy was carried out in the ESTEC 2 metre solar simulation chamber at Noordwijk, Holland, in four phases, starting in December 1965 and ending in June 1966.

Brief Description of the Chamber. The chamber is a stainless steel cylinder with a liquid nitrogen cooled shroud. This shroud is built up of a number of serrated extrusions which in turn are painted matt black to give a high absorptance of incident energy. The cylinder has its axis vertical and the satellite is mounted in a ring section near the top of the chamber. Five "Genarco" carbon arc lamps illuminate the spacecraft through ports in the base of the chamber. The sting on which the satellite is mounted has the facility for spinning the satellite over a range of speeds, as well as to tilt the satellite spin axis relative to the chamber axis. The sting does not rotate continuously in one direction but reverses its direction of rotation every two revolutions. This enables temperatures on the satellite to be sensed by means of Copper-Constantan thermocouples, the wires being fed down a spiral inside the sting to a junction plate on the outer wall of the ring.

The cold junction is electrically maintained at 0° C to an accuracy of $\pm \frac{1}{4}$° C. The potential difference across each of the thermocouples is selected in turn by a Hewlett Packard Data logger, displayed on a digital volt meter, printed by a Hewlett Packard Printer and punched on paper tape by a Tally Perforator. The punched tape is fed into a computer which converts the millivolt readings to degrees and prints out temperatures against channel number and time at which the reading was taken.

Test Phase I—December 1965. The ESRO II satellite came at an early stage in the existence of the European Space Research Organization, and the installation of the test facility at Noordwijk proceeded in parallel with the ESRO II programme. Thus it was apparent at an early stage that the carbon arc solar simulators would not be installed and operative in the chamber in time for the first thermal dummy test phase in November/December 1965. This test phase was, therefore, scheduled to be a heater blanket test in which an electric blanket was wrapped around the honeycomb solar panels—no cells were fitted at this stage. Liquid nitrogen was pumped through the shrouds to simulate the heat sink of space and electrical power was supplied to the blanket to maintain the honeycomb panels at the temperature at which the mathematical model predicted they would operate if illuminated by one solar constant. The internal units dissipated the correct powers and the one hundred thermocouples distributed about the dummy were monitored. It was thus possible to compare the measured temperature distribution with predicted values.

The tests carried out during this phase were to simulate the full Sun orbit with normal internal power dissipation for two insulation standards—one with insulation blankets behind the panels and the other with no insulation behind the panels.

Despite the comparative crudeness of the test, a considerable amount was learned from the results. The test highlighted an error of assumption in the first of the two tests in which the radiation coupling between the Sun-seeing structure and the internal equipment and structure was incorrectly calculated resulting in poor correlation between measured and predicted temperatures.

With the insulation removed from behind the panels, predictions compared well with measured values. Computer runs, subsequent to the tests, gave calculated values which agreed much more closely with the measured temperatures for the insulated case when modified assumptions were incorporated in the mathmatical model.

The measured temperatures also showed that excessive gradients existed along the centre tube and that there was a substantial heat loss from the satellite via the mounting sting. As a result, it was proposed that the protruding dome of the S29 experiment be provided with a multilayer insulation cover and that an insulating block be fitted between satellite and sting in the next test.

Test Phase II—January 1966. For this phase of testing, the carbon arc lamps were operative. It was too early for full standard solar cells to be available but very similar thermal characteristics were achieved by painting the outer face of the honeycomb panels with a green paint having substantially the same absorptance and emittance as the cells.

The programme of tests proposed and carried out was more ambitious than the heater blanket phase and, in fact, turned out to be too ambitious for the operational status of the

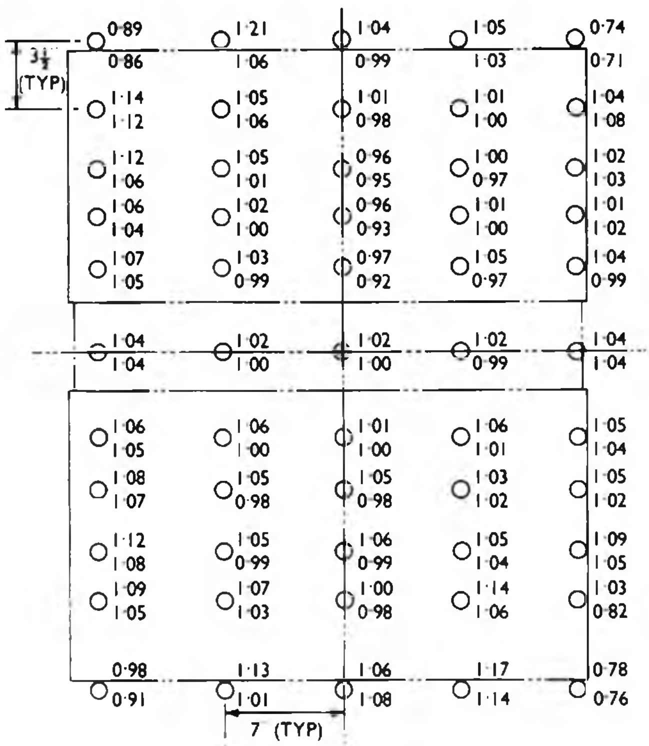


Fig. 7. Pre-test calibration—55 Pts. = 1·04 suns, and post-test calibration—55 Pts. = 1·00 suns. 1·0 sun position.

facility. Besides the full Sun orbit with normal power mode, a number of simulated orbits of 63 min illumination and 37 min eclipse with normal power mode, and subsequently with economy power dissipation, were run to check thermal capacities. This was followed by tests in which the satellite was inclined towards the source by 40° to simulate the possible errors at injection into orbit.

The tests showed that the insulating block was insufficiently effective in reducing conductive heat loss to the sting in a test of this duration.

Progressive degradation of the lamps resulted in a steady decrease in intensity throughout the test. The time available to the ESTEC personnel to measure intensity distribution in the target area and to obtain experience in operating, cleaning and maintaining continuous operation of the lamps since installation, had been insufficient with the result that limited correlation was possible between measurements and predictions, especially later in the test phase.

It was decided that before any further testing, a suitable procedure for operating and cleaning lamps would have to be evolved, the intensity of the lamps would have to be measured before and after the test to assess degradation, lenses would have to be cleaned during the test and a better method of in test intensity monitoring utilized. During the January phase, intensity was monitored at the target plane by means of two small water-cooled thermopiles. The area of these was felt to be too small to give a true impression of average intensity variation during testing.

To eliminate heat loss to the sting, future tests would be carried out with an electrically operated sting heater between the sting and satellite. The satellite mounting ring and the sting flange would then be maintained at the same temperature.

Calibration Phase—March 1966. An array of 25 copper plates, 3 in × 3 in, painted black on the front face and insulated on the rear face, was suspended by means of poor-conducting strings in a Paxolin framework and the whole assembly mounted in the target plane in the chamber. Thermocouples were attached to the back faces of the plates to enable temperatures to be obtained. Four more plates were suspended, two either side of the array, in the monitoring position.

The lamps were operated and plate temperatures recorded at frequent intervals. When the intensity had dropped by 10%, the lamp lenses were changed.

The test was repeated for different lamp combinations and the variation of intensity, together with monitor plate readings obtained for each lamp combination.

Test Phase III—April 1966. As a result of the March calibration, the April test phase was very successful and good agreement between predicted and measured temperatures obtained.

The results of the January phase enabled the final solar panel insulation standard to be decided with insulation fitted only outboard of the end covers. Because of the better coupling between panels and equipment a temperature variation was set up around the floors which was traced to the fact that the sting was not turning a whole number of turns in each direction resulting in the "overlap" area receiving more energy than the remainder.

A test was included in this phase with the spacecraft mounted inverted to the sting, via an adaptor in place of the S29 experiment. This test was invaluable in highlighting the fact that the S28 and Scout attachment flange area were running much colder than predicted. The Scout attachment flange, when exposed to space conditions, ran cold and hence drew heat down the centre tube making it cold and hence S28 too. Additional insulation, between the experiment and the tube and covering as much of the attachment flange as possible, was proposed.

The April test phase was the only one in which the thermal dummy had actual solar cell covered panels fitted.

Test Phase IV—June 1966. The June test was for the sole purpose of demonstrating that the extra insulation, fitted in the S28 area, was sufficient to eliminate the problems of low temperature in the experiment. The test was carried out with the satellite inverted throughout and was not completely successful. A return of the earlier lamp operating problems, together with the fact that the S28 experiment was still operating at too low a temperature, made the test something of a disappointment.

Additional insulation to eliminate the view of the still cold tube above the experiment floor was proposed together with insulating washers under the experiment mounting feet.

The thermal dummy test programme was successful from a number of aspects. At the end of the programme a thermal design standard had been decided upon which was incorporated into the second prototype and both flight spacecraft and was not subsequently changed.

A very large amount of experience was obtained in solar simulation testing and an appreciation gained of the problems encountered. It was felt that Design Approval and Flight Acceptance testing could now be successfully carried out.

Some of the tests which were attempted on the thermal dummy were of doubtful value, especially when the operational status of the chamber is borne in mind. The ESTEC Environmental Test engineers worked extremely hard to calibrate lamps, achieve good distributions, obtain intensity plots, maintain lamp operation, assess degradation with time, etc., so that the ESRO II thermal test programme could stay on schedule. In fact, there simply was not time for them to obtain intensity plots either side of the nominal one sun plane, to achieve optimum lamp operation and to sort out all the inevitable teething troubles of the installation prior to testing.

TABLE I—*Measured and Predicted Temperatures P2 & F1 Solar Simulation Tests*

Item	Chamber Measurements °C		Chamber Predictions °C	PREDICTED ORBIT TEMPERATURES °C		
	P2	F1		100% Sun Nominal Inputs	100% Sun Maximum Inputs	Maximum Eclipse Minimum Inputs
Cells-inboard	6	5	10	24	32	−31
outboard	3	4	9	23	31	−37
Experiments:						
S.25	14	8	8	21	30	− 6
S.27	6		7	21	30	− 6
S.28	− 9	−8	−9	6	16	−16
S.29	5	1	0	15	24	− 8
S.36	8	7	8	21	30	− 6
S.37 Sensor/P.A.	10	14	8	21	30	− 6
S.37 Electronics	6	4	7	21	30	− 6
S.72 Sensor	4	0	4	19	28	− 7
S.72 Electronics	9	3	7	21	30	− 6
Floors and equipment	5−12	4−8	7−8	21	30	− 6
Top end cover	−11	−16	−14	5	15	−22
Bottom end cover	−14	−10	−12	7	17	−21

9.2.2. *Prototype Tests—December* 1966. Although solar simulation testing of the P2 satellite was originally scheduled to take place in the ESTEC facility, this plan had to be changed to allow construction of the building to proceed and the decision was taken to test P2 in the 30 ft diameter TRW Systems facility at Redondo Beach, California. In this chamber, the satellite is mounted to the sting with the cover supported separate from the chamber and the whole assembly is lifted into place in the chamber. The six carbon arc lamps shine horizontally and all six operate to give one solar constant. The sting is of the continuous rotation type with a rotation speed of 30 rpm. Temperatures were sensed by means of 50 thermistors and the signal transmitted from the thermistors to the chamber wall via slip rings and brushes.

Intensity measurements were taken prior to the test at the nominal one Sun position, at two planes behind this and at one in front. Since the rotation gear could be moved towards and away from the lamps, it was possible to position the satellite such that the average intensity over the illuminated cells was one solar constant.

The modification to the thermal build standard recommended at the end of the thermal dummy testing, namely additional insulation of the S28 experiment, was incorporated. Also, the satellite had fitted to it nine thermistors which were part of the telemetry system.

The test phase was carried out in two parts, the first with the satellite mounted by its Scout attachment flange and the second with S29 replaced by an adaptor to mount the satellite in the inverted position. In each case, temperatures were measured for the simulated full Sun orbit, normal power mode, followed by one simulated maximum shadow orbit to check thermal capacities and comparison between the in-flight thermistors and the additional instrumentation under transient conditions.

Comparison between predicted and measured temperatures was good and is shown in Table I. The adaptor for the inverted test disturbed conditions locally but the S28 experiment was outside this area of disturbance. The changes to the insulation standard were successful and, indeed, no changes were necessary to any part of the mathematical model.

The TRW Systems facility is fully developed and lamp operation was completely satisfactory. Rod changes took less than 1 min every 45 min for each lamp during which time the lamp was out of operation and cleaning took place. Degradation, as shown by intensity distribution measurements after each test phase, was small.

9.2.3. *Flight Model Tests—January* 1967. The F1 satellite was tested in the TRW facility by measuring full sun stabilized temperatures only, with the satellite mounted at the Scout attachment flange. Although there were some minor differences between P2 and F1 measured results, agreement was good between F1 measured and predicted temperatures (Table I).

10. Orbit Temperatures

The ESRO II satellite was scheduled to be launched in the period 1–17 March 1967. It was hoped to include temperatures telemetered from the satellite in orbit but due to non-availability of the Scout fourth stage the launch has been delayed to late April. Table I shows the nominal, maximum and minimum temperatures expected in orbit during the satellite's life.

Reference

1. C. R. Hume, "The ESRO II satellite project", *Spaceflight*, 9, 20, 1967.

Acknowledgements

The authors wish to thank the Directors of Hawker Siddeley Dynamics Limited for permission to publish this paper.

REVIEWS

Edited by L. J. Carter

Books reviewed in *SPACEFLIGHT* are now available on loan to all members of the British Interplanetary Society resident in the United Kingdom. Applications for loans *must be sent by post* to the Executive Secretary of the Society at 12, Bessborough Gardens, London, S.W.1, enclosing 3s. 6d. (minimum postage rate). Books will be issued to applicants in strict rotation. Members who would like to be added to the Society's Panel of Reviewers are invited to write to the Books Editor, including an outline of their particular interests and/or specialization.

Extraterrestrial Civilizations. G. M. Tovmasyan (Ed.), Israel Program for Scientific translations, Jerusalem, 1967 (Translated from the Russian), 99 pp., published for NASA, $4.00.

This volume contains the thirteen papers presented at the first Conference on Extraterrestrial Civilizations and Interstellar Communication, held at Byurakan Observatory in 1964.

The *existence* of EC (extraterrestrial civilizations) is taken for granted—the conference was concerned only with the technical problems of communication between EC and ourselves. So far as our own attempts at receiving such communications are concerned, these problems can be broadly divided into: (*a*) in what part of the sky shall we look for signals?, (*b*) in what part of the electromagnetic spectrum shall we listen? and (*c*) if we hear something, how shall we know whether it really is a signal from an EC?

All these points, and others, receive attention in this book, some of them being covered by more than one paper. For example, N. S. Kardashev divides EC into three types according to their available power resources: Type I is equivalent to our present Earth civilization, Type II has harnessed the power of its sun, and Type III has harnessed the power of its galaxy. (Between Types I and III there is a factor of 1025 in available power). He goes on to show that there could be several Type II EC in our galaxy, and that with our present technology we should certainly be capable of picking up their signals; the main problem is distinguishing between the signals from EC and those from natural sources. He puts forward three "artificiality criteria": spectrum peaked in the 3–10 cm range, falling off linearly in the high frequency region; source of small angular size; and signal variable in time. Other speakers described the application of these criteria to signals from certain selected radio sources, but—rather disappointingly—were obliged to conclude that the existence of EC remained "not proven."

A paper by S. E. Khaikin makes the point that EC at a higher level of development than ourselves must know the capabilities of lower-level civilizations, and must therefore know how they would attempt to decode the signals from EC. He argues that EC will therefore deliberately code their signals so that lower-level civilizations will be able to understand them. He also concludes that EC will probably wait until lower-level civilizations radiate "ready" signals, indicating that they have reached a state of development at which they are capable of decoding the EC's signals, before they (the EC) start transmitting. He strongly recommends that we should start sending "ready" signals straight away, otherwise we shall never receive any extraterrestrial communications at all. He goes on to discuss the form that these "ready" signals should take.

Both Khaikin and a later speaker, V. S. Troitskii, show that our present resources are certainly good enough for us to communicate with a large number of EC (if they exist), but we must tackle the job systematically and we must be prepared to allocate our best radio-telescopes to this task. Provided that we do this, we should be able to detect even our own Earth-type civilizations if there are more than one per 10^6 stars.

Although the technical problems of communicating with EC are discussed at length in this volume, none of the contributors gives much thought to the desirability—or otherwise—of doing so. The reader looking for answers to philosophical questions such as why EC should *want* to communicate with us will be disappointed. Electronic engineers, however, provided that they are not overwhelmed by the thought of energy outputs of 10^{44} ergs/sec, may well find the book stimulating.

J. R. MILLBURN.

Project Nero (M.I.T. Report No. 10). MIT, 1967, 260 pp., $7.50.

In the Spring of 1966 a Systems Engineering Student team at the Massachusetts Institute of Technology (MIT) examined the feasibility of Near-Earth Rescue and Operations (NERO). The team of twenty-four students, taking part in the Advanced Space Systems Engineering Course, have now published the results of their study in a 260-page report. The preface states that the object of the report is "not to present a technical proposal," rather to record "an experience in education"—and this is essentially what it does.

The task given to the student team was to examine the problem of designing the salient features of an all-purpose orbital shuttle capable of performing the many service and support-type missions envisaged for 1970–75. The applications considered for such a vehicle are rescue, inspection, supply and repair of satellites and spacecraft in orbit. It is suggested that the very pessimistic figure of up to seventy-five missions a year might be required by 1975, mostly on inspection and repair work.

The design deliberately stays within the bounds of existing technology and the vehicle quickly takes shape in the book. A Titan IIIC is used to launch the NERO spacecraft which goes into orbit with a two-man crew. The re-entry element closely resembles the NASA lifting body research vehicle, for which due recognition is given in the report. Missions could last hours, or days, and would end with a controlled re-entry and turbo-jet powered approach and landing at a suitable airfield in the free world. All major systems are reviewed in the report, none of them too deeply, but ample references are given in each section of the book. Those familiar with the costs of advanced projects may be surprised to read an R & D cost of less than £500 million, and may also disagree with the estimated low production cost of £600,000 for each of the first twenty-five copies. Of course there is the additional cost of about £5 million per launch for the Titan IIIC.

Professionally produced and well edited, the report avoids the pitfalls of modern American "technicalese." At times elementary points are laboured, but this is not a bad thing in a report of this kind. In fact the reviewer found the reiteration of fundamental facts very helpful at times. However this is not a reference book. Its broad brush treatment of all vehicle systems could be useful as an up-to-date teaching example for technical colleges. Lastly, at 54s. the book cannot be recommended for the engineer's personal bookshelf, except perhaps for the specialist budding space systems designer.

A. KEDAN.

Astronomy Old and New. By E. A. Beet, Bell, 1967, 198 pp., 25s.

This book is a general review of astronomy designed for students, sixth-formers and amateur astronomers and provides a comprehensive overall picture of astronomy. It provides compact, but readable descriptions of the night sky, traditional astronomical equipment, telescopes and their accessories

and more recent astronomical investigations with radio telescopes and spacecraft.

The Moon and Earth are discussed—including a short description of atomic theory, the planets, there is a short chapter on solar system debris and the book ends with descriptions of the Sun stars, galaxies, radio sources and current problems in astronomy. There are numerous line diagrams in the text, sixteen plates, including one of the 20-days old Moon alongside an outline chart, a fold-out star chart of the northern and southern skies and an index.

The information is correct up to the end of 1966 thus the old value of Mercury's rotation period is given in the table on page 99 and no mention is made of *Janus*, Saturn's tenth satellite. A helpful feature of this handy, but brief, volume is the list of references of books and periodicals readily available in this country, at the end of each chapter.

This is not a book of practical astronomy: the armchair astronomer will benefit by this volume as will, in fact, teachers of astronomy and general science. The printing and production are good and the price is very reasonable.

G. FALWORTH.

The Search for Life on Other Worlds. By Capt. C. Holmes, Oak Tree Press, 1967, 240 pp., 25s.

Literature on life on other planets is expanding at an alarming rate. A bibliography compiled four years ago listed over 1500 papers, articles and books: a similar list compiled today would probably be twice as long. This is the more surprising when one considers that there is still no conclusive evidence that life exists anywhere except on Earth.

Writing a book on life beyond the Earth needs some courage, for one can only describe the very fragmentary and inconclusive results of Earth-based experiments, and then spend the rest of the time discussing *possible* future experiments and the results that they *might* reveal. Such a book *has* to be, largely, speculation.

Yet this is clearly an exciting topic and even a book of speculation should make interesting reading, so it is with regret that this reviewer has to report that he was bored by the present volume. It is full of cliches, the writing is pedestrian and the few attempts at humour are childish. It is also written at such a low technical level as to be positively misleading in places. For example, on page 146 hydrocarbons are called carbon atoms with hydrogen atoms attached, while on page 69 it is stated that ice crystals have been detected in the atmosphere of Venus, a "fact" which is highly disputed.

Perhaps the most disturbing thing about this book is its bias. Almost every person mentioned is American. There is no discussion at all of contributions from other countries, and the Soviet space effort might as well not exist. One scans the index unsuccessfully for such basic names as Oparin, Haldane, Fesenkov, Pirie, Bernal, Tijhov, etc.

M. H. BRIGGS.

22nd Annual General Meeting

Chairman's Speech

The 22nd Annual General Meeting of the British Interplanetary Society was held at Caxton Hall, London, S.W.1, on 19 October 1967, with Mr. K. W. Gatland (*Vice-President*) in the Chair.

Mr. Gatland welcomed those present and said that he proposed to take the President's speech as read, since this had been circulated beforehand.

The year 1966 has seen two very successful events for the Society *i.e.*, the tour of the Spacemobile which had proved a great success, which was the kind of educational activity which the Society wished to encourage, and also the presentation to the Soviet Academy of Sciences to mark the first successful soft-landing on the Moon.

Another event was the non-appearance of the *Journal*. This was a negative accomplishment but it was necessary in order that we could develop *Spaceflight* and give more coverage to current developments. While *Spaceflight* "held the fort" the Council had been considering and developing ideas about how the *Journal* might be re-issued, and this would be discussed later.

In order to make any real headway, we must endeavour to increase our membership significantly. A 50% increase in our total membership would place us in much clearer waters than we were today. The Council was not satisfied, by any means, with the development of the Society from the point of view of its total membership, and was continuing its endeavours to the utmost to improve on our position.

Statement of Accounts and Balance Sheet

The Executive Secretary pointed out that the accounts were similar to the preceding year, the major difference being the heavy increase in expenditure on publications, which had risen from approx. £6500 to £7800, and which seemed likely to increase still further in view of the apparently endless rise in printing costs. Fortunately, we had been able to balance our budget for the year, though the surplus was very slight and left much to be desired.

Administration expenses had been kept to a minimum and were constantly being examined to see if any further way presented itself in which economies could be made.

The Chairman remarked that our administration expenses had been cropped so often that they were now almost below ground-level!

Dr. G. V. Groves (*Fellow*) in proposing that the accounts be accepted, said that the Meeting as a whole would like to note with satisfaction the economies made and that the Society, in coming out on the positive side, had acquitted itself very well. After seconding by Mr. J. Marshall (*Associate Fellow*) the accounts were carried unanimously.

Discussion then centred on the report of the Trustees on the Benevolent Fund Account. This was still increasing slowly and we were gradually approaching our target of £3000.

The Society now had a growing number of long-standing members who had supported its activities consistently over many years, and each year brought us closer to the time when the Benevolent Fund would play a very real part in our activities.

On the proposal of Mr. N. R. Nicoll (Fellow), seconded by Mr. F. R. Smith (Fellow) the Accounts were approved.

The Secretary then introduced the first Accounts for the Golovine Award, which had reached the initial target of £1000. The first presentation of the Golovine Award was currently being considered by the Honours and Awards Committee, but it was already clear that there was a tremendous amount of work, reflected in published material, which the Society ought to recognize and acknowledge as representing support of and contributions to astronautics. It would probably prove difficult to make a single award, which would do justice to the many diverse areas, and there was no doubt that this was an aspect which the Society could usefully develop.

On the proposal of Mr. S. Buchanan (*Fellow*), seconded by Baron A. Manhattan (*Member*) the Accounts were unanimously approved.

The Society's Council

The Scrutineers reported that a total of 565 voting papers had been received, of which two had been spoilt, and the result of the Ballot was as follows:—

K. W. Gatland	528 votes
Dr. M. A. Bodin	370 „
K. J. Ball	368 „
C. T. Wilkins	336 „
Dr. M. H. Briggs	307 „
Dr. A. E. Slater	285 „
Dr. G. A. Heath	273 „
E. B. Dove	246 „

The Chairman proposed that the names of the first five persons receiving the greatest number of votes be duly elected to the Council, and this was approved unanimously.

Mr. S. Buchanan then moved that the meeting approve a vote of thanks to the three unsuccessful candidates, particularly mentioning Dr. A. E. Slater, who had been a Member of the Council for 22 years and who had been unsuccessful in the Ballot.

This was seconded by Mr. E. Norman-Wilson (*Fellow*) and carried unanimously.

General Discussion

Journal. The Executive Secretary opened the discussion by providing further information on the *Journal*, which was due to be re-issued in March 1968 in a much-improved format and which he hoped would prove to be a really first-class expression of the Society's technical ability.

The Editorship of the *Journal* would be handled by Dr. G. V. Groves, with Dr. N. H. Langton as Assistant. They, in turn, would be supported by a Panel of Referees covering the whole spectrum of astronautics activities. The first two issues would include papers presented at the recent Space Biology Symposium and there appeared every likelihood that these would prove of wide general interest.

The initial circulation was expected to be of the order of 1000 copies, with 800 copies as the break-even point.

Assistance was needed from members who would like to help in proof-reading material for both *Spaceflight* and the *Journal* and any offers received would be greatly welcomed.

In reply to a question, the Executive Secretary agreed to obtain a Council decision on whether copies of the *Journal* would be sold individually to members having a particular interest in one issue, though he pointed out that—if there was an excessive demand for one issue which had not been seen beforehand—the result might be that we should be unable to make up complete sets for subsequent sale.

Mr. Norman-Wilson (*Fellow*) suggested that *Spaceflight* should list the contents of forthcoming Journals beforehand, to enable members to make up their mind on the question of purchasing a copy in good time, and so enable this to be incorporated in the print order.

Education

Samples of educational material currently being distributed by the Society were exhibited, and a discussion took place on how this might be extended.

Mr. C. Cromarty (*Senior Member*) said that it was still extremely difficult to convince many people that astronautics was a natural development in the history of mankind, and not merely an expensive game.

In reply, the Executive Secretary agreed with that analysis and compared conditions in the U.K. with conditions in Soviet Union, where astronautics is taught in many schools—where considerable pride is felt in their space achievements, and with America where teachers are supported by an extensive educational programme undertaken by NASA, which included the provision of about 40 Spacemobiles touring the entire country.

There were approximately 80 000 establishments in this country where astronautics could usefully be taught, but in the great majority of these, the subject was cold-shouldered by tutors. The Society probably reached about 1000 of these establishments each year. This represented the extent of interest at the present time and it seemed unlikely that this could be greatly increased unless teachers and students felt some affinity with astronautics, *i.e.*, until such time as it was accepted, as a matter which concerned them.

One current activity in which we were engaged to foster this interest was the preparation of a five-volume series on astronautics teaching at universities which was due to be published in 1968.

Membership

Mr. C. H. Blake (*Fellow*) pointed out that, while it was necessary for the Society to adopt a professional attitude to push itself ahead and to influence thinking in other parts of the country, we should make it clear that the non-technical member is equally necessary and to be welcomed in this activity.

The Chairman wholeheartedly agreed with this, and pointed out that, even where technical aspects were considered, many professional people were amateurs in other areas of astronautics.

Mr. N. R. Nicoll (*Fellow*) mentioned that the work of the Branch Programme Committees was designed to provide meetings which were attractive to both technical and non-technical members, and to deal with astronautics in general terms.

Meetings

The Chairman drew attention to the Society's arrangements to hold an Annual Meeting each year, the first of which would be held in Southampton on 24–25 April 1968. The plan behind these was to arrange some major meeting with a theme of particular interest to a wide audience, and the first subject chosen was "The British National Launcher Programme." It would deal "in depth" with both the Black Arrow launcher and the satellite programme associated with it, and would also include social activities.

If this proves successful, it might be possible to expand this to a major Society activity in the future.

Generally, film shows had proved very successful and attracted good audiences. The excursions had also been very well supported, as were the various special meetings arranged to allow members to meet some distinguished person in the field of astronautics.

A suggestion was advanced that the Society should hold a more ambitious meeting, *i.e.*, including an excursion to America with visits to, *e.g.*, Cape Kennedy.

The Executive Secretary promised to look into this, but mentioned that this had already been the subject of a previous examination, which had disclosed that the cost per person was formidable, and depended heavily upon the allocation of every seat in the aircraft.

The meeting was then concluded.

SOCIETY NEWS

18th IAF Congress, Belgrade, Yugoslavia

The 18th IAF Congress, held at the Youth House, Belgrade, during the period 24–30 September 1967, attracted an attendance of around 600 delegates from all parts of the world.

As before, a wide range of subjects was dealt with in depth during the technical sessions, which were supported by specialist symposia on education in astronautics, history of astronautics, space law, the lunar international laboratory and orbiting laboratory.

In addition to the technical sessions, a large number of working sessions took place during the whole of that week, when delegates met together to plan the future scope and activities of the Federation, and to further its interests.

Among the decisions taken were the following:—

(*a*) *Finance*. The Federation suffers acutely from lack of adequate finance, and it was agreed that the registration fee of future Congresses should carry a \$10.00 surcharge which would be payable to the Federation to recover part of its congress costs.

(*b*) *Brochure*. The IAF is to undertake the preparation and publication of a brochure detailing its aims and history since 1950.

(*c*) *Awards*. The IAF will re-instate the Gunter-Loeser Medal, originated in 1954, and expand its interest in making awards in recognition of outstanding contributions to astronautics.

(*d*) *Congress Sessions*. An attempt is to be made to evaluate these and to prepare standards for technical, general and social levels for future Congresses.

(*e*) *Special Studies*. A number of opportunities were presented for *ad hoc* committees to be set up to study various specialized aspects of astronautics—in particular, a long-range Planning Group might prove very fruitful.

(*f*) *Educational Activities*. A special study should be made of opportunities for research in astronautics in universities throughout the world, particularly with regard to the exchange of students between different countries.

(*g*) *History of Astronauts*. As the first History of Astronautics Symposium proved so successful it was decided to continue this and also to recommend that a permanent committee for history be set up with the initial aim of documenting international co-operation in space over the past 10 years.

(*h*) *President*. Professor L. Napolitano was elected President of the Federation for a second year. Other Members of the Bureau included Dr. W. H. Pickering (Past President), Professor L. Sedov, Professor H. H. Koelle, Professor Andjelic, and Professor Carefoli (Vice-Presidents).

(*i*) *Next Congress*. The 19th IAF Congress will be held in New York in October 1968.

Reports Available for Loan

Reports listed below can be borrowed by any member in the U.K. or Western Europe on application to the Executive Secretary, British Interplanetary Society, 12, Bessborough Gardens, London, S.W.1, quoting the report number and enclosing 1s. (or two international reply coupons) to cover postage. Please specify which issue of *Spaceflight* lists the particular reports required. Loans are restricted to a period of one month.

Number	Title	Authors
D-4185	Entry flight aerodynamics from Apollo mission AS-202.	Ernest R. Hillje
CR-784	Auxiliary power systems for a lunar roving vehicle.	E. P. Erlanson
CR-822	Analysis and design of space vehicle flight control systems. Volume III—Linear systems.	Arthur L. Greensite
CR-823	Analysis and design of space vehicle flight control systems. Volume IV—Nonlinear systems.	Arthur L. Greensite
CR-828	Analysis and design of space vehicle flight control systems. Volume IX—Optimization methods.	Arthur L. Greensite
CR-831	Analysis and design of space vehicle flight control systems. Volume XII—Attitude control in space.	Arthur L. Greensite
CR-832	Analysis and design of space vehicle flight control systems. Volume XIII—Adaptive control.	Arthur L. Greensite
CR-833	Analysis and design of space vehicle flight control systems. Volume XIV—Load relief.	Robert D. Harris
CR-834	Analysis and design of space vehicle flight control systems. Volume XV—Elastic body equations.	Arthur L. Greensite
CR-846	Launch vehicle wind and turbulence response by nonstationary statistical methods.	James E. Bailey, *et al.*
CR-854	Light sources for remote sensing systems.	M. W. P. Cann
CR-855	Isothermal and isophotic atlas of the Moon. Contours through a lunation.	J. M. Saari & R. W. Shorthill
CR-859	Study of astronaut capabilities to perform extra-vehicular maintenance and assembly functions in weightless conditions.	E. C. Wortz, *et al.*
CR-861	Study of ceramic heat shields for lifting re-entry vehicles.	J. N. Krusos
CR-865	Electromagnetic guidance study.	J. H. Lowry
CR-868	Plasma boundary interactions.	S. Aisenberg, *et al.*
CR-870	Lunar Orbiter I. Extended-mission spacecraft subsystem performance.	
CR-871	Some considerations of manned extravehicular activities in assembly and operation of large space structures.	H. Schuerch
CR-882	Liquid sloshing in elastic containers.	Helmut F. Bauer, *et al.*
CR-889	Biomagnetics—Considerations relevant to manned spaceflight.	Douglas E. Busby
CR-892	Development of a prototype plastic space erectable satellite.	Vincent F. D'Agostino & Preston Keusch
SP-134	The closed life-support system.	
SP-153	Symposium on computer simulation of plasma and many-body problems.	
SP-3024	Models of the trapped radiation environment. Volume IV—Low energy protons.	Joseph H. King
SP-3030	Handbook of the physical properties of the planet Mars.	C. M. Michaux
TT F-455	Problems of astrophysics.	Ye. P. Fedorov

ESRO REPORTS

Number	Title	Authors
SN-2	Computer programme on attitude perturbations and magnetic control of a spin-stabilised satellite.	H. G. Walter & K. G. Lenhart
SN-65	Scientific experiments in ESRO satellite project project TD-2.	A. P. Willmore
TM-91	Some remarks on the attitude of quasi-symmetric rockets.	H. Kummer

OTHER REPORTS

Number	Title	Authors
P-16	SAE Conference proceedings. Space Technology Conference, 1967.	

Concluded from page 75]

Personal

A. V. Cleaver, O.B.E. (Fellow) has been elected an Honorary Fellow of the American Institute of Aeronautics and Astronautics. A former chairman of the B.I.S., Mr. Cleaver has played a leading part in developing the RZ.2 rocket engines used in the HSD Blue Streak which forms the first stage of the ELDO Europa space launcher. His latest activities concern the RZ.20 lox/hydrogen chamber of 13 000 lb thrust.

Mr. Cleaver was recently appointed General Manager of the Rocket Department of the Rolls-Royce Aero Engine Division at Ansty, near Coventry, where British industrial work on ELDO powerplants and Gamma series rocket engines for the national satellite launcher Black Arrow will now be concentrated. At the same time time as his appointment as General Manager, Mr. Cleaver was made a director of the Rolls-Royce Industrial and Marine Gas Turbine Division.

Obituaries

We regret to record the death of **Mr. Frederick Burgess Taylor** (Member) at the age of 41 years.

The late Mr. Taylor, who joined the Society in 1946, was educated at St. Bees, Cumberland and Universities of Manchester and Oxford. The former awarded him the degree of Master of Science and Queens College Oxford gave him his Master of Arts degree.

For some years he was engaged on research into rocketry at I.M.I. Summerfield, Kidderminster. At the time of his death he was a Marketing Director of Imperial Aluminium Company (Wales) Limited.

We also regret to record the death of **Dr. Stanley Charles Ghose** (Fellow) at the age of 56 years.

For 10 years following the war, Dr. Ghose was Consultant to the Royal Air Force Central Medical Establishment on the applications of science to medicine and surgery. Prior to his death, he was Scientific Consultant to EMI Limited, on the electronics of guided weapons. He also advised on matters affecting applications of electronics to medicine and applied physiology.

Classified Advertisements

Advertisements, with remittances, should be sent to Cheiron Press Ltd., 5, Crawford Street, London, W.1 (01-935 2814). Rate 2s. per word, minimum £1 10s. Panels £5 an inch. Box numbers 6s. extra. Replies to Box numbers should be sent to the same address.

Spaceflight

Spaceflight is published monthly by the British Interplanetary Society, and is issued free to members.

Full particulars of membership may be obtained from the Executive Secretary at the Society's offices at 12, Bessborough Gardens, London, S.W.1; telephone 01-828 9371.

Correspondence and manuscripts intended for publication should be addressed to the Editor at 12, Bessborough Gardens, London, S.W.1.

Opinions in signed articles are those of contributors, and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society, unless such is expressly stated to be the case.

Forthcoming Meetings

WESTERN BRANCH FILM SHOW

To be held in the Large Lecture Theatre, Queen's Building, University of Bristol, University Walk, Bristol on **1 February 1968,** at 7.30 p.m.

The programme will include the following:—

(1) Ranger 9.

(2) Engineering Aspects of Ariel 3.

(3) Meeting in Space.

(4) Gemini 12.

(5) Diary of an Astronaut.

1ST ANNUAL MEETING

The Society plans to hold an Annual Meeting, beginning in 1968, as part of its programme of activities.

The first Meeting will be held at the University of Southampton during the period **24–25 April 1968.** This will be residential, with full board provided.

The theme of the Meeting will be "The British National Launcher Programme" with the aim of providing an overall view of the Black Arrow Programme.

An outline of the programme is as follows:—

April 23. *Excursion.*

An afternoon excursion by private coach from the University to the High Down Test Site (used for Black Arrow tests) of Westland Aircraft, will return to the University for a programme of films.

April 24. *Launchers.*

(1) A review of existing vehicles and sub-systems, containing the latest performance data.

(2) The possibility of uprating vehicle payload capabilities.

(3) Adaptation of high-energy upper stages, etc., and possibility of mating with ELDO vehicle.

(A total of 8 papers will be included.)

An informal dinner will be held in the evening.

April 25. *Utilization Satellites.*

(1) Papers on data handling, telemetry, technological and scientific experiments, structure, etc., of the S1 satellite.

(2) The theme of the S2–Sn satellite series.

(3) Ion motors and large solar cell arrays.

(A total of 6 papers will be included.)

Full details of the programme, registration forms, will be available shortly. Further enquiries, offers of papers and other correspondence should be addressed to the Secretary.

8TH EUROPEAN SPACE SYMPOSIUM

This will be held in Venice during the three-day period **27–29 May 1968.** It is being organised jointly by the AIR, BIS, DGRR, SFA, and with the support of EUROSPACE.

A total of 22 papers will be presented on the theme of "*Technological Aspects of Scientific Satellites.*"

Subjects to be included will be experimentation, instrumentation, attitude control, power supplies, orbits, and the construction, operating and data acquisition and reduction aspects of scientific satellites—but from technological aspects only, *i.e.*, excluding scientific results.

Translation into English will be provided.

Offers of papers and other enquiries should be addressed to the Secretary.

SPECIAL MEETING AND PRESENTATION

A special meeting will be held on Wednesday, **21 August 1968,** in the Botany Theatre, University College, Gower Street, London, W.C.1, beginning at 7 p.m.

A Certificate of Honorary Fellowship will be presented to Dr. George E. Mueller, Associate Administrator for Manned Space Flight for the National Aeronautics and Space Administration, in recognition of his significant contributions to astronautics over a long period.

After the presentation, Dr. Mueller will deliver an address to the Society.

Please note change in date previously advertised.

19TH INTERNATIONAL ASTRONAUTICAL CONGRESS

The Society is endeavouring to arrange a charter flight for members and their families who plan to attend the 19th I.A.F. Congress **13–19 October 1968.**

If a plane can be filled, a considerable reduction in cost, £60–65 per head, *i.e.*, less than half of the regular fare, can be made, but early application is needed if these arrangements are to be finalized in time. Members who wish to attend are invited to notify the Executive Secretary immediately, enclosing a deposit of £15, which will be refundable if the arrangements do not materialize.

Further details will appear in forthcoming issues of *Spaceflight.*

List of Films

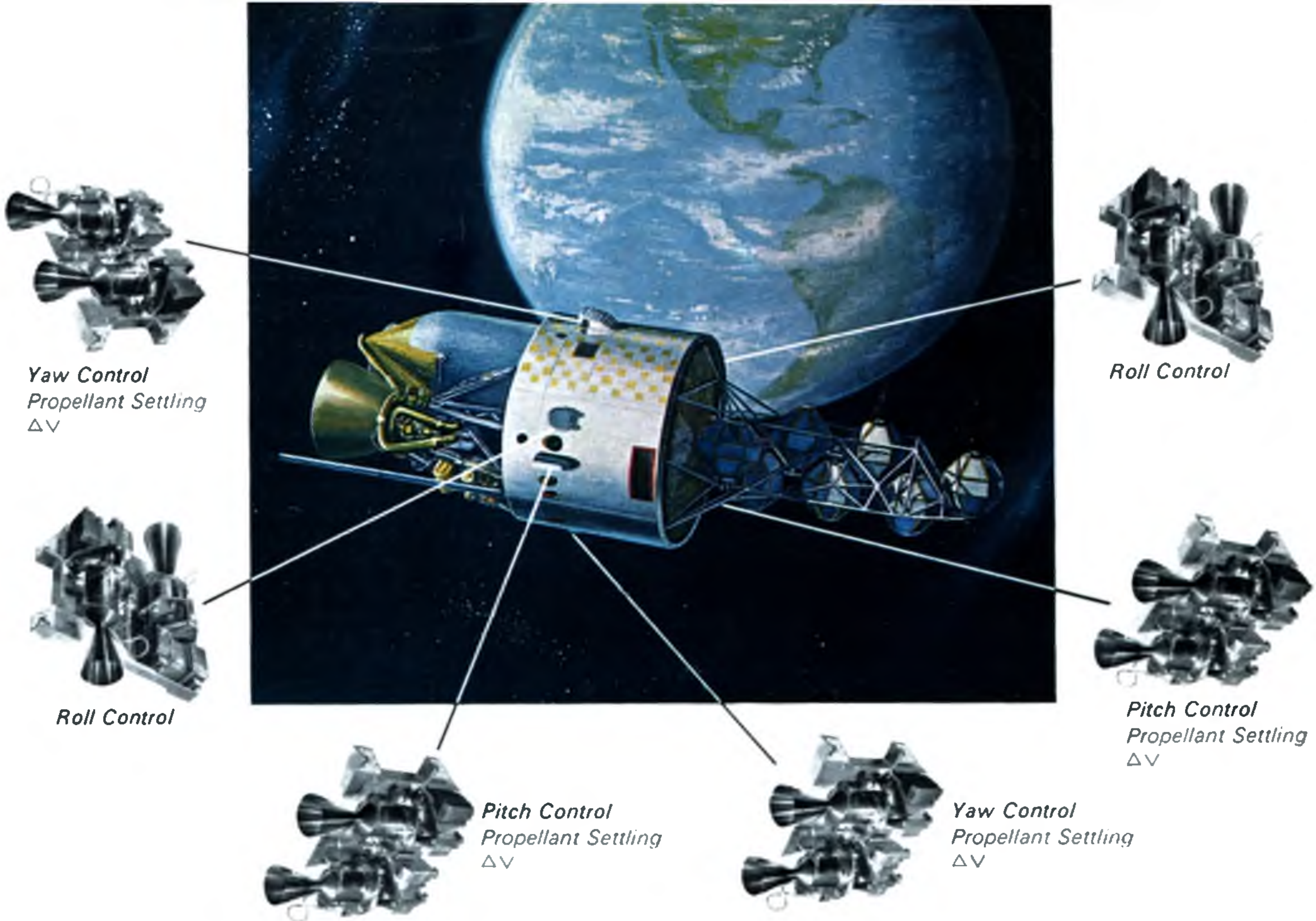
A number of films are available to members of the Society for use in lectures. These cover a wide range of subjects from rocket technology, astronomy and current space activities generally, and are frequently brought up to date.

A list of those available is obtainable on request, enclosing a foolscap reply-paid envelope.

Wallchart

A copy of the USAF *Aerospace Environment Wallchart* (40 × 33 in) is available to members able to use it for lectures and educational purposes. Please forward 4s. to cover postage and packing.

Printed by W. Heffer & Sons Ltd., Cambridge, and Published by The British Interplanetary Society, 12, Bessborough Gardens, London, S.W.1.
Advertisement enquiries to: Cheiron Press Ltd., 5, Crawford Street, London, W.1 (01-935 2814).



Transtage joins the switch to hydrazine

Twelve Rocket Research monopropellant hydrazine rockets will provide precise attitude control propellant settling, and velocity addition control for the Titan IIIC Transtage. Each employs a blow-down pressurization system providing about 25 lbf thrust.

Martin Marietta selected monopropellant control rockets for the job because of their history of reliability and cost savings. And hydrazine rockets can provide unmatched response, reproducibility, linearity and performance under minimum impulse bit operation.

Tests have demonstrated performance at 10 msec pulse widths superior to comparable bipropellant rockets; reproducibility of these small impulse bits was within ±5%.

Outstanding characteristics coupled with the advanced development status of monopropellant hydrazine systems put these rockets in immediate contention for many new applications . . . and Rocket Research is ready to provide them, ready with complete capability—from design and management through manufacture, test and delivery—developed over 4 years of leadership in the monopropellant hydrazine field.

Rocket Research has received more than 30 contracts for hydrazine propulsion systems, developed rockets from .02 to 300 lbf; developed, manufactured, qualified and delivered control rockets to NASA, Navy, Air Force and industry. New control rocket hardware is being developed for the Air Force Ballistic Systems Division (PBPS attitude control), NASA (Astronaut Hand-Held Maneuvering Unit for EVA) and the Navy (NRL satellite) as well as Transtage.

The expert knowledge gained by experience, the talents of top hydrazine engineers and scientists gathered from throughout the nation, the capability developed to meet the requirements of major contracts are available to you—when you make the switch to hydrazine. Call Ralph Eide, Director of Marketing.

ROCKET RESEARCH CORPORATION

520 South Portland Street, Seattle, Washington 98108
Telephone 206-ROcket 2-1560

Spaceflight

Volume X

1968

Editor: KENNETH W. GATLAND, F.R.A.S., F.B.I.S.

Published by the British Interplanetary Society
12, Bessborough Gardens, London, S.W.1

Foundations of Soviet Cosmonautics*

By G. A. Tokaty†

Gregory A. Tokaty (Tokaev) was born in 1910 in North Caucasus, Russia. Because of the First World War, the February and October revolutions of 1917, the disastrous Civil War of 1918-21, and the famine of 1921-22, his formal education did not commence until 1929, when, at the age of 19 years, he attended the Workers' Faculty of the Leningrad Mining Academy. It was continued from September, 1930, at the Workers' Faculty of the Moscow Higher Technical College (MVTU), from which he graduated in May 1932. One month later, he was mobilized to become a student of the Zhukovsky Academy of the Soviet Air Forces, one of the most famous educational and research establishments in aeronautics and space technology in the world.

In May 1937, G. A. Tokaty-Tokaev successfully graduated from the Academy with the degree (or diploma) of D.Eng. and the military rank of Senior Lieutenant of Engineering Service. In June of the same year he became a Research Engineer and, in July 1938, Head of the Laboratory of Aerodynamics of the Zhukovsky Academy, with the military rank of Captain of Engineering Service. This important appointment put him at once in close working contact with the main research and development establishments of the Soviet Air Forces, such as the Central Hydro- and Aerodynamic Institute, and the Flight Testing Institute of the Air Force, and the aircraft industry. At the start of the Nazi-Soviet war, already a Ph.D. and Staff Lecturer at the Academy, he began working on the introduction into service of the new aircraft MiG-1, MiG-3, Yak-1, LaGG-1, Pe-2, Tu-2 and others, and later of the American Aerocobra, Mustang, B-25C, and the British Hurricane. In 1942, now Major of Engineering Service, Member of the Learned Council at the Zhukovsky Academy and Acting Professor of Aviation at the Moscow Engineering Institute, he began leading courses in aircraft design, rocket-dynamics and aerodynamics.

From about 1933, when for the first time he met Konstantin Tsiolkovsky, G. A. Tokaty was a rocket enthusiast, and from 1938 he was associated with rocket work at the Academy and elsewhere. In June 1945, he was sent by the Soviet Government to Germany where he worked immediately under Marshals of the Soviet Union G. K. Zhukov and V. D. Sokolovsky, in due course to become Chief Rocket Scientist of the U.S.S.R. in Germany, responsible to Stalin himself. Since 1948, Col. Tokaty has lived in Great Britain; he is now Professor and Head of the Department of Aeronautics and Space Technology at The City University, London.

Kenneth W. Gatland

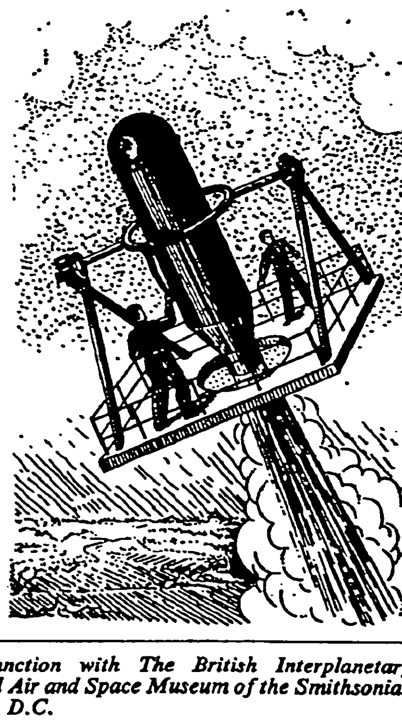
Introduction

In the Western World there still exists today a degree of reluctance to take the Soviets for what they are, a sort of refusal to understand "those Russians," a kind of thinking that scientific cleverness and technological inventiveness are non-Russian qualities. I find this particularly disturbing in relation to aeronautics and space technology, because they represent the *to be or not to be* of our epoch, and do not tolerate either unfounded prejudices or traditional attitudes; this is a broad field of modern achievement where the knowledge of facts has already become as important as the facts themselves.

But what are the facts? Let me say right away that, in my judgment, the Russian-Soviet scientists and technologists always were, and remain, as intelligent, as clever and as inventive as the British, Americans, Germans, French and the others; that in such fields as mathematics, theoretical physics, space technology, and automation, they display an even greater sophistication and progress faster than some of the older scientific-technological civilizations in the world.

N. I. Kibul'chich (1854–81).

Take, for example, rocketry, which is the vanguard of modern knowledge and may easily be described as the most complex of all the technologies. Russia entered this field at least simultaneously with the Western countries, certainly in the 18th century. Already in 1848–66, Konstantin Ivanovich Konstantinov (1817–71), a Russian artillery general, studied such fundamental problems as discharge of powder gases, the critical cross-sectional area of the discharge stream, the external configuration of a rocket, methods of stabilization of rockets in flight, the thermo-mechanical structure of a powder rocket, rocket launchers, etc. And while reading his results, I feel convinced that he was to Russia as clever and as inventive as Sir William Congreve was to England. Then, in 1870, another Russian artillery general, Ivanin, advanced the idea of a winged rocket. Eleven years later, in 1881, Nikolai Ivanovich Kibal'chich (1854–81) put forward an idea for a man- and load-lifting vehicle propelled by compressed-powder rockets. Again, five years later, a certain engineer, Evald, experimented in Petersburg with the model of a rocket-propelled aeroplane.



Kibul'chich's man-lifting rocket.

* *Prepared in conjunction with The British Interplanetary Society and the National Air and Space Museum of the Smithsonian Institution, Washington, D.C.*

† *Head, Department of Aeronautics, City University, London.*

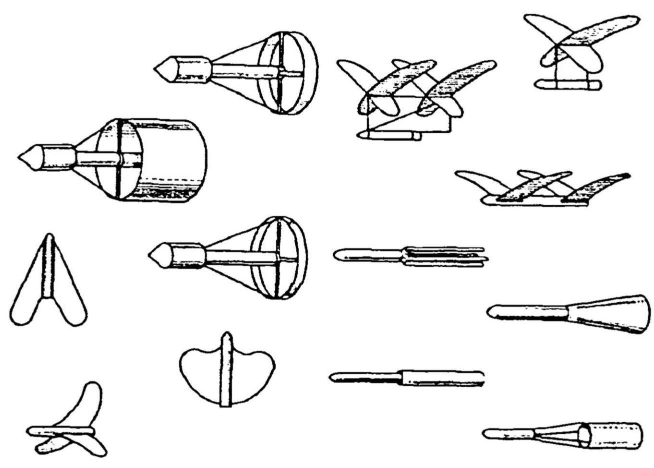
And so on, and so forth. During only the second half of the 19th century at least twenty projects, or project-like ideas, of rocket-propelled flying machines were suggested in Russia by Konstantinov, Ivanin, Kibal'chich, Evald, Gashvend, Tretesky, Sokovnin, Teleshev, Nezhdanovsky, Fyodorov, and others.

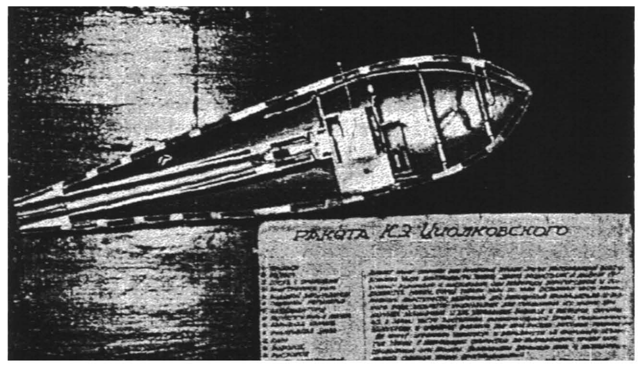
From 1900 onwards, these ideas and inventions were continued by a new generation of Russians, among whom the most prominent was, perhaps, Mikhail Mikhailovich Pomortsev (1851–1916), yet another artillery man. He alone worked out, and presented to the authorities, eighteen projects: six-winged rockets, one rocket with fixed stabilizers, and eleven rockets with exceptionally interesting cylindrical lifting and stabilizing devices. "I was so much impressed by Pomortsev"—recalled the late D. P. Riabouchinsky in 1961—"and he had such an acute inventive mind, that I at once offered him all the advice and help he asked for. His achievements were already quite significant, but he wanted to push ahead with still more exciting ideas, including the idea of a rocket propelled aeroplane. . . ."

Tsiolkovsky

But Konstantin Edvardovich Tsiolkovsky (1857–1935) was, of course, the greatest of them all. Back in 1883, in his work *Svobodnoye Prostranstvo* (Free Space), he had expounded the principle of jet propulsion for flight in the vacuum of space, and in 1903, in another work called *Issledovaniye Mirovykh Prostranstv Reaktivnymi Priborami* (Exploration of Space by Reactive Instruments), he developed it into a revolutionary proposition. An elongated configuration of least aerodynamic drag; liquid hydrogen and liquid oxygen propellent supplied to the combustion chamber by mixer valves; divergent nozzle; cosmonaut's compartment—these and other aspects of his theory and project were elaborated in great detail. By 1915, he had developed the project still further—to such a stage of technological completeness that its basic concept and ideas remain valid up to this day.

These are facts available in museums and recorded in written history. But there are also some other facts which should be borne in mind. For example, Russia entered the present century with outstanding contributions to the general front of knowledge. Here are some of the very many examples: "Periodic system of chemical elements" (by D. I. Mendeleev, 1869); "The dynamics of a point of variable mass" (by I. V. Meschersky, 1897); "The kinematics of a fluid body" (by N. E. Zhukovsky, 1875); "On the theory of flight" (by N. E. Zhukovsky, 1890); "On the flight of birds" (by N. E. Zhukovsky, 1891); "On the angle of incidence of an aeroplane" (by N. E. Zhukovsky, 1892); the famous "Zhukovsky or Kutta-Zhukovsky Theorem" (1906); "On the theory of gas-streams" (by S. A. Chaplygin, 1904), and so on. In addition, the Moscow University Aerodynamic Laboratory was built in 1902–04, the Kutchino Aerodynamic Institute in 1904–06, and the Moscow Higher Technical College Laboratory of Aeronautics in 1910–12. Equally, or even more important, back in 1909, Professor Nikolai Egorovich Zhukovsky (1847–1921) began lecturing on "Osnovy Vozdukhoplavaniya" (Foundations of Aeronautics). On the basis of these lectures, and of the laboratory of Aeronautics, a school, or circle, of Aeronautics was formed at the Moscow Higher Technical College (MVTU), and this became, in 1915–16, the main centre of study, research and development of aviation in Russia; by 1919 it had developed into the Central Aero- and Hydrodynamic Institute, CAGI, today the largest and one of the most up-to-date aerospace research centres in the world. Then, in 1919, the Zhukovsky Academy of Aeronautics of the Soviet Air Forces came into being, and began influencing the whole way of aerospace thinking in the U.S.S.R.





Top, Pomortsev's experimental rockets *circa* 1900 (after V. A. Tarassov's article in "*Iz Istorii Raketnoi Tekhniki*," Moscow 1964).

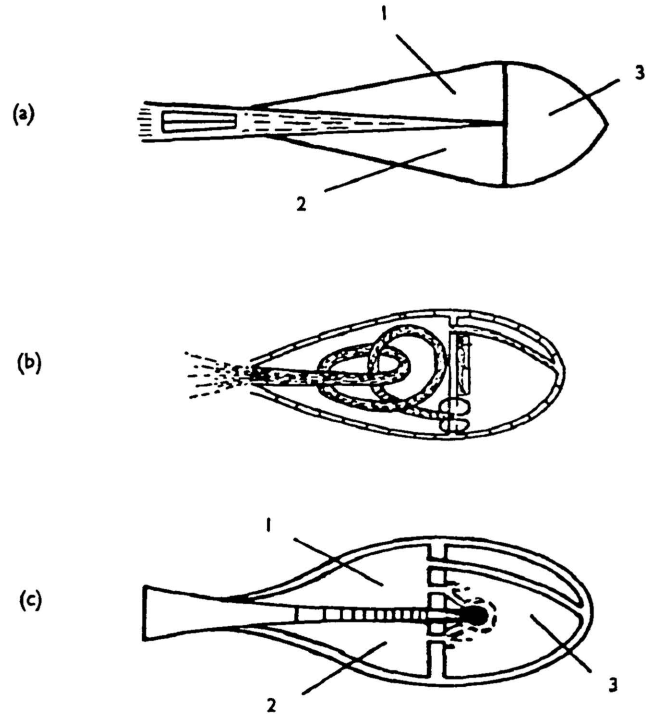
Bottom, Tsiolkovsky's model of a "spaceship" made in 1903. *Novosti Press Agency*

However, the 1914–17 World War, February and October revolutions of 1917, disastrous Civil War of 1918–20, and dreadful famine of 1921–22, brought about indescribable sufferings and slowed down the further growth of aviation and rocketry, therefore Tsiolkovsky—the enthusiast—did not reappear, really, until about the second half of the twenties. Nevertheless, I was a very happy man—he said to us in 1933—because, in spite of all the great difficulties, the spirit of space exploration was re-emerging from the ruins of the epoch with a new vigour.

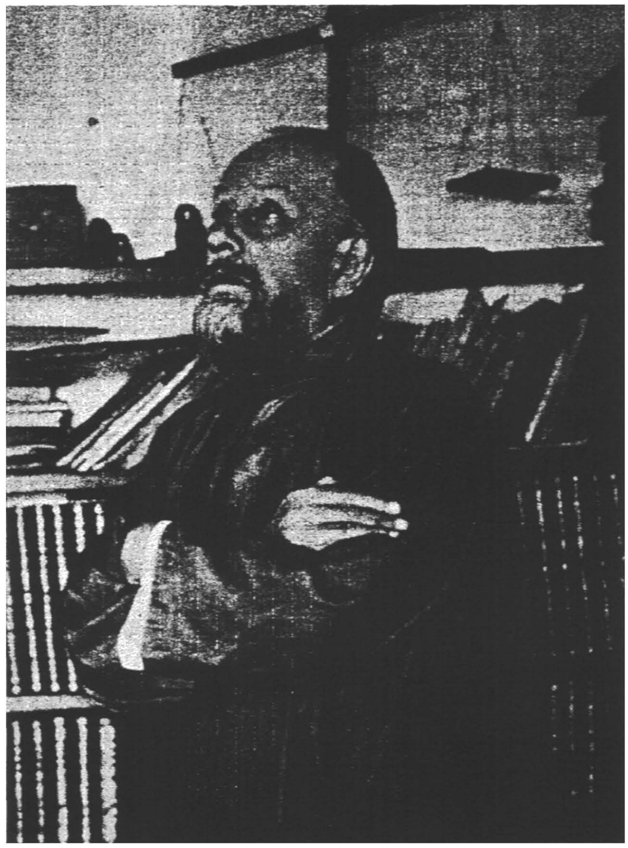
The Gas-Dynamics Laboratory (GDL)

Indeed, already in 1921, Soviet engineers N. I. Tikhomirov and V. A. Artemyev had organized in Moscow the first Soviet powder rocket laboratory. In 1927, this was moved to Leningrad and became in 1928 the Gas-Dynamic Laboratory (GDL) of the Revolutionary Military Council (RVS, the name of the Ministry of Defence of the U.S.S.R. at the time). The GDL worked under the general supervision of M. N. Tukhachevsky, then Head of the Department of Armaments at the RVS, in due course Marshal of the Soviet Union and Deputy Minister of Defence, while its operational Chief was Tikhomirov.

Then, in the spring of 1924, at the Zhukovsky Academy in Moscow, a "Gruppa Mezhplanetnykh Soobschenii" (Group of Interplanetary Flights) was formed. In May of the same year, it was reorganized into an "Obschestvo po Izutcheniyu Mezhplanetnykh Soobschenii" (Society for the Study of



Tsiolkovsky's rocket proposals: (*a*) 1903 concept: 1. Liquid hydrogen; 2. Liquid oxygen; 3. Man, including absorption of carbon dioxide and odours. (*b*) Original illustration, 1914, from Tsiolkovsky's publication "Exploration of Space by Reactive Instruments" (additions to chapters I and II). (*c*) 1915 concept: 1. Liquid oxygen, freely evaporating at very low temperature; 2. liquid hydrogen; 3. People, breathing apparatus, instruments, etc.

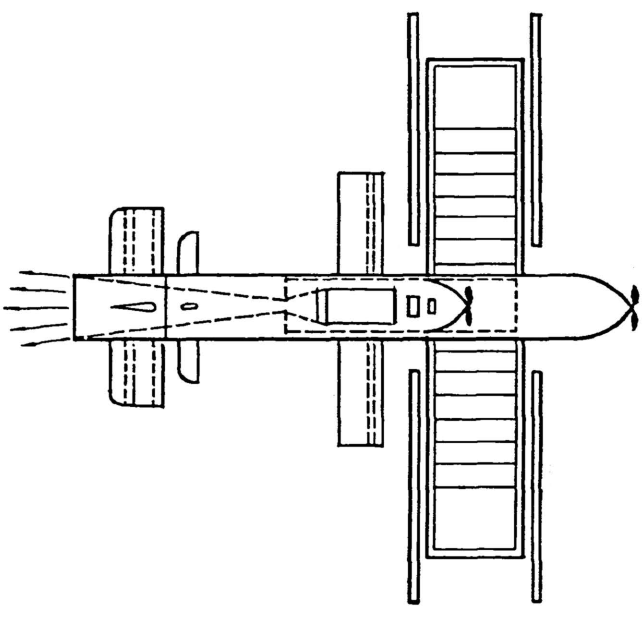


Konstantin E. Tsiolkovsky (1857–1935).

Interplanetary Flights). Largely on the initiative of this Society, two new bodies were formed in 1931: "Central'naya Gruppa po Izutcheniyu Reaktivnogo Dvizhenia" (Central Group for the Study of Reactive Motion, CGIRD, in Moscow, under the chairmanship of F. A. Tsander, and "Leningradskaya Gruppa po Izutcheniyu Reaktivnogo Dvizhenia" (Leningrad Group for the Study of Reactive Motion), Len-GIRD, under the chairmanship of N. A. Rynin.

It is interesting to mention that none of these was hidden behind an "iron curtain," at least up to about 1935–36. Tsiolkovsky's ideas were open to the world, both in print and through letters to foreign rocket pioneers. Professor Rynin's outstanding work *Mezhplanetnyie Soobscheniya* (Interplanetary Communications) was published, openly, in 1929–30; and so were books and articles by Yu. V. Kondratyuk, and others. It was widely known, for example, that Friedrich Arturovich Tsander (1887–1933) was working on a spacecraft project from about 1909, which in 1924–25 caused quite a sensation among the rocket enthusiasts of the time.

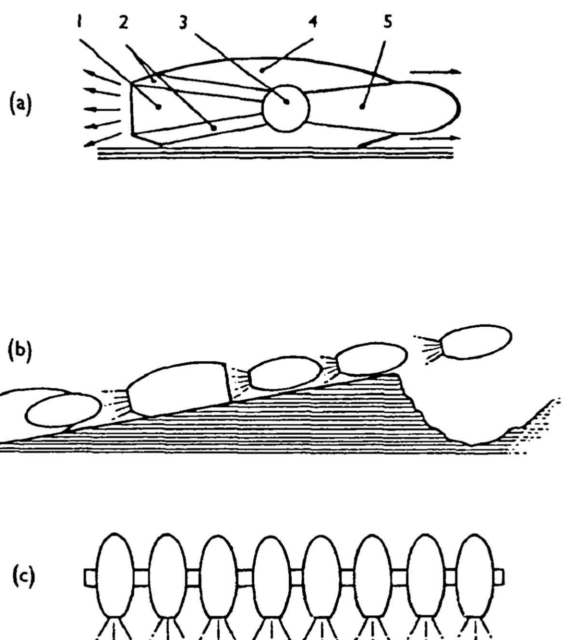
Tsander's project consisted of large and small aeroplanes integrated in such a way that their fuselages entered the body of the spacecraft. The wings, tailplanes, engines and propellers were to be used for take-off and flight within the atmosphere, and after that pulled inside the ship to melt them into a liquid aluminium; in turn, this would be used as fuel for the rocket motor of the main ship (the idea of the use of metals as a fuel having been put forward by Tsander back in 1910). It was also in this project of 1924 that he proposed to use the reversed rocket thrust for re-entry braking.



Tsander's rocket aeroplane proposal of 1924–25.

Frederich A. Tsander (1887–1933).

The still more tangible epoch of rocketry began in the U.S.S.R., however, in 1930–32, towards the end of the first Five-Year Plan of industrialization. This was a period of re-moulding the Soviet Air Forces. The New CAGI, the Central Institute of Aircraft Engine Construction (CIAM), the Scientific Testing Institute of the Air Forces (NII-VVS), the Scientific Research Institute Number One (NII-1), the All-Union Institute of Aviation Materials (VIAM), and many other establishments of aeronautics, were already either planned or in the process of construction.



Above, two versions of Tsiolkovsky's 'rocket trains' (step rockets). Top diagram shows a two-stage rocket for ramp-launching. 1. Combustion tube; 2. Petroleum; 3. Machine (meaning pumps); 4. Oxygen, or oxygen compound; 5. Cosmic rocket. Centre diagram—in Tsiolkovsky's words—shows "The path of a ground rocket over mountains, and of a cosmic rocket—over mountains and beyond. In reality the path is twice as steep." Bottom diagram illustrates an alternative proposal in which rockets are mounted in parallel.

Right, first Soviet rocket engine ORM-1 developed by GDL (Leningrad) in 1931.

Quite naturally, all this boosted Soviet rocketry also. Tsiolkovsky re-appeared with several new theories and projects, of which the more important were: "A new aeroplane" (1928); "The reaction engine" (1927–28); "The acceleration of an ascending rocket" (1930); "Jet-propelled aeroplane" (1929); "The theory of the jet-engine" (1930–34); "The maximum speed of a rocket" (1931–33); "Space rocket trains" (1924–34), and others. Some of these original contributions were also studied by other people. For example, Yu. V. Kondratyuk published (1929) a fundamental work called *Zavoyevaniye Mezhplanetnykh Prostrasnstv*—Conquest of Interplanetary Space. Prof. Boris Sergeevich Stechkin, who in due course became a leading theoretician in the field, published an article (1929) which has every right to be called the first fundamental thermogasdynamic jet/rocket propulsion theory (Tsiolkovsky's contribution on this subject was both independent and much more bulky, and the range of questions discussed in it was wider).

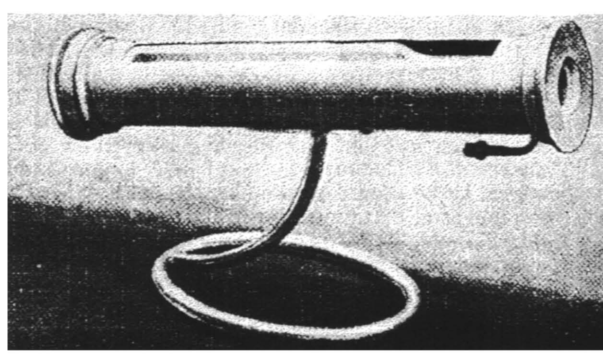
The "rocket trains" constitute Tsiolkovsky's last major contribution to space technology. It was bulky, full of mathematical details, and with rigorous elaboration of the methods and techniques of design and operation of such "trains," *i.e.,* multistage rockets. "But I am not at all sure, of course"—he said to a group of Zhukovsky Academy students in 1934—"that my 'space rocket train' will be appreciated and accepted readily, at this time. For this is a new conception reaching far beyond the present ability of man to make such things. However, time ripens everything; therefore I am hopeful that some of you will see a space rocket train in action. . . ."

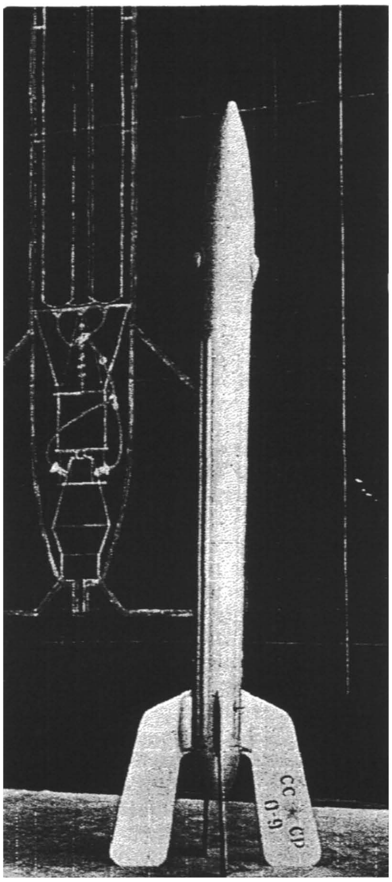
First Soviet Rocket Engine

Tsiolkovsky died on 19 September 1935. But his ideas were already in firm and able hands. His "train"—multistage rocket—was already under study. On 15 May 1929, a jet/rocket department was formed in the Leningrad GDL. Here, in this department, was designed, constructed and tested (1931) the first Soviet Opytnyi Reaktivnyi Motor (Experimental Reaction Motor) ORM-1; it worked on benzene and liquid oxygen and produced up to 20 kg of thrust. At the same time, the Moscow GIRD was developing Tsander's engine "Opytnyi Reaktivnyi No. 1," or OR-1, which worked on benzene and produced (1932) a thrust of 5 kg.

In April 1932, the Government created in Moscow the first Soviet rocket design and experimental development establishment, under the leadership of a still young engineer and pilot called Sergei Pavlovitch Korolyev—the future "mysterious" Chief Constructor of the Vostoks and Voskhods. This was the first page in the official (*sic*) history of Sputnik 1 and Yuri Gagarin.

There were several groups in Korolyev's organization. One of them, under F. A. Tsander, developed an improved version of OR-1 called OR-2, the thrust of which reached 50 kg. The second group, under M. K. Tikhonravov,





Left, replica of GIRD R-09, the first Soviet liquid-propellent rocket launched on 17 August 1933.

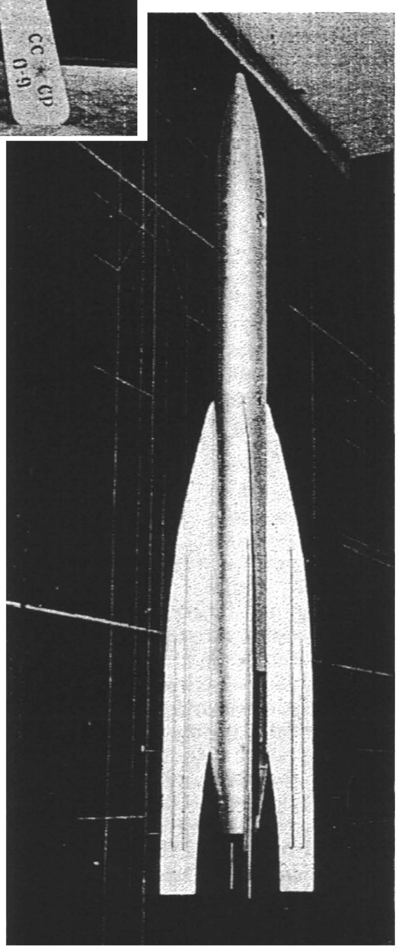
All illustrations Novosti Press Agency. from K.E. Tsiolkovsky State Museum, Kaluga.

worked on the development of rocket vehicles, and on 17 August 1933, launched the first Soviet rocket, then known as R-09, whose characteristics were: weight 19 kg, length 2·5 metres, diameter 0·18 metres, thrust 50 kg. On 25 November, the second rocket, GIRD-X, or No. 10, was launched; its characteristics were: weight 30 kg, length 2·2 metres, diameter 0·14 metres, thrust 29 kg. The leading figures behind these two rockets were: S. P. Korolyev, M. K. Tikhonravov, L. S. Dushkin, L. K. Korneyev, A. I. Polyarnyi, and F. A. Tsander (died 28 March 1933).

Creation of the RNII

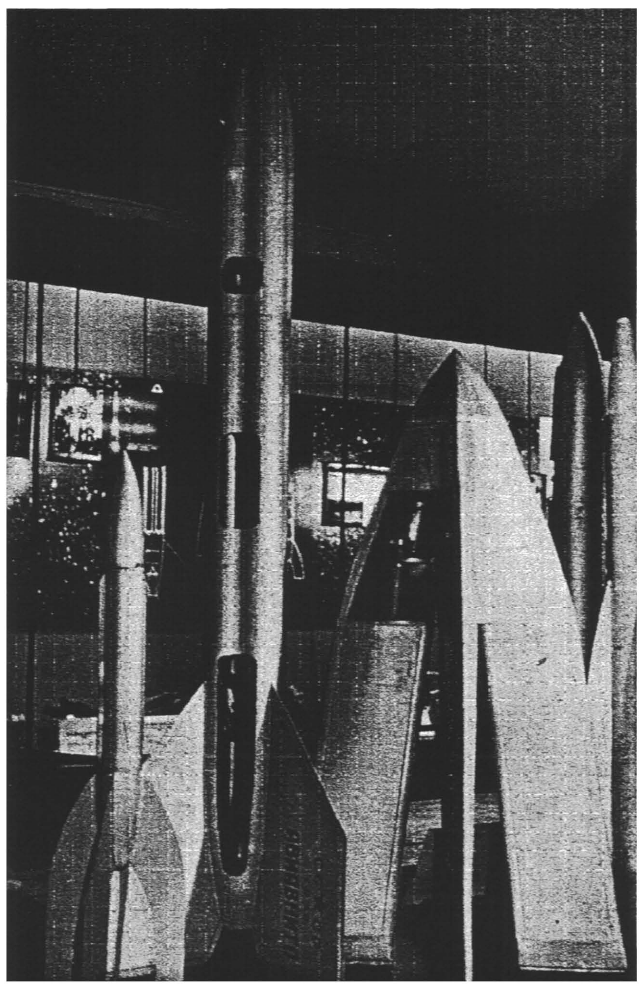
In December, 1933, the government resolved to rationalize the scattered system of GIRDs into a Reaktirnyi Nauchno-Issledovatel'kii Institut (Reaction Scientific-Research Institute), RNII, in Leningrad; this absorbed also the GDL. I. T. Kleimenov and S. P. Korolyev became the Head and Deputy Head, respectively, of RNII. But members of the GDL and GIRDs were allowed to continue their projects which had started before the rationalization.

From then until about the beginning of the Soviet-German War, RNII was the main centre for research and development of rockets of all kinds. For example, the famous military rocket BM-13, or "Katyusha," was designed there by a group under A. G. Kostikov and G. E. Langemak. Within the RNII, the GDL developed a whole series of rocket propulsion units, from ORM-23 to ORM-102, and increased the absolute rocket thrust from 20 kg in 1931 to about 320 kg



Right, replica of GIRD R-10 launched on 25 November 1933.

Extreme right, examples of Soviet experimental rockets of the period 1933–36, amongst them—second from left—the 10 ft long "Aviavnito" which reached a height of 3.5 miles.

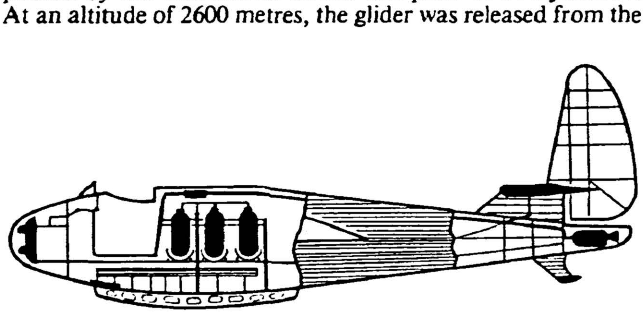


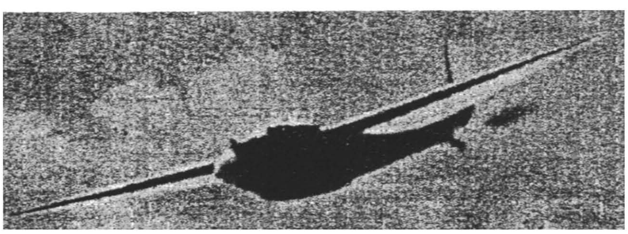
A group of young Soviet rocket enthusiasts in 1935, including—fourth from right—the future Vostok designer S. P. Korolyev.

in 1937. No wonder that on 24 April 1936, the U.S.S.R. launched successfully a rocket called "Aviavnito" of 3 metres length, 0·3 metres diameter and 300 kg of thrust; on 15 August, the same rocket was launched and reached an altitude of 2400 metres.

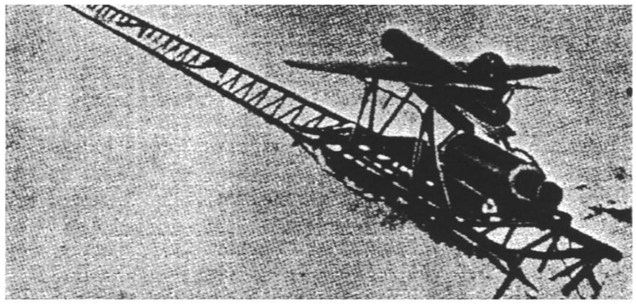
Rocket-propelled Aircraft

The idea of a winged rocket put forward a long time ago by Evald, Konstantinov, Pomortsev, Tsiolkovsky, Tsander and others, too, was far from being dead. In 1935–36, a group of RNII under S. P. Korolyev, worked on the experimental study and design of such a machine known as "Project 212." This was an automatically-controlled, pilotless aircraft on similar lines to the German V-1 flying-bomb of World War 2. But its ORM-65 propulsion unit was mounted *under* the tailplane. Project 212 was tested thirteen times on the ground in 1937–38, and then in flight in 1939. Its essential characteristics were: total weight 210 kg, weight of propellent (nitric acid + kerosene) 30 kg, weight of explosives 30 kg, length 3·2 metres, wing span 3 metres, range 50 km. On 28 February 1940, a Soviet P-5 military aircraft towed into the sky a somewhat unusual glider; this, too, was Korolyev's design, a rocket-plane, RP-318-1, piloted by the well-known Soviet test pilot V. P. Fyodorov. At an altitude of 2600 metres, the glider was released from the





In 1940 the first Soviet rocket gliders were demonstrated. Drawing shows Korolyev's RP-318-1 which flew successfully, below, in February 1940.



Project 212, a pilotless aircraft similar to the German V-1 "flying-bomb" but rocket powered. Designed in 1935–36 under S. P. Korolyev, it was testflown in 1939.

tow-cable and its rocket engine ignited. Speed immediately increased from 80 to 140 km/h in 5 to 6 sec and in about 110 sec it had climbed some 300 metres. And so the history of the rocket-plane began in the U.S.S.R.

Soon after these successful flights, S. P. Korolyev said to Prof. B. N. Your'ev and myself, in my office, that "Pretvoreniye idey Tsiolkovskogo v zhizn' stalo vozmozhnym"—the putting of Tsiolkovsky's ideas into practice has become a possibility. But two months or so later, again in my office at the Zhukovsky Academy, he remarked that the government had decided to give the task of designing the first Soviet operational rocket-propelled fighter not to him but to Victor Fyodorovich Bolkhovitinov. "Why," he asked, "don't they trust me?" We were sure they trusted him. But Bolkhovitinov was already a well-known aircraft designer, a gifted theoretician, and a Colonel of Engineering Service, a Zhukovsky Academy man. Besides, there was plenty for Korolyev to do: he had been instructed to continue working on Project 212 in a 212A version.

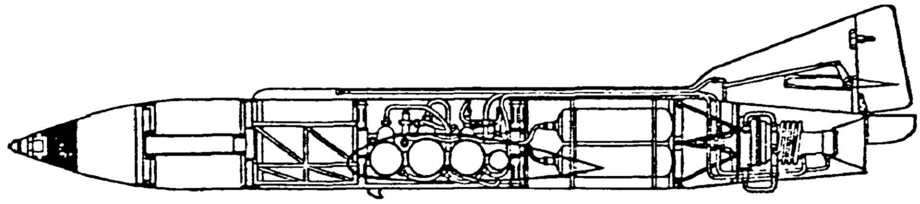
Victor Bolkhovitinov, now a general of aviation and Professor of aircraft design at the Zhukovsky Academy, was my teacher, colleague and friend. We lived in the same Academy house at 24 Furmannyi pereulok. He began working on a rocket-plane in 1939 and I was familiar with all stages of the project.

I should like to include here a little information totally unknown in the West. In 1940–41, V. F. Bolkhovitinov gave a long series of special lectures—to the academic staff of the Zhukovsky Academy—on the aerodynamic and structural design of a rocket interceptor. I attended all these lectures and I think they were the first lectures of the kind in the U.S.S.R.; they certainly made a tremendous impact. From then on, we had a clear idea of how such an aeroplane should be designed.

Bolkhovitinov was actually talking about the aircraft on which he worked. Its prototype was ready in the summer of 1941; but Nazi Panzer divisions were fast approaching Moscow, and it, too, had to be evacuated to the region of Sverdlovsk. There, on 15 May 1942, before my eyes, the first Soviet rocket fighter BI-1 (BI = Bolkhovitinov, Istrebitel = Fighter) took off from a military airfield. It was piloted by G. Ya. Bakhchivandji. For about 15 to 20 minutes, the third flight was again a complete success; but then suddenly BI went out of control, and that was the tragic end of both the aircraft and the pilot.

The rocket motor of BI-1 was the same as of Korolyev's RP-318-1, *i.e.*, RDA-1-150 designed by L. S. Dushkin; its thrust could be varied in flight from 350 to 1400 kg. Yet when I mentioned these facts to a German jet test pilot and his colleagues in Dessau in 1945, he replied smilingly that "the Me-163A must have been the first rocket-plane in the air. . . ." I smiled back and said that, yes, of course, everything new and original must have been German.

Right, side elevation of Korolyev's winged rocket, Project 212A, of 1937–39, which showed many advances over the original design.



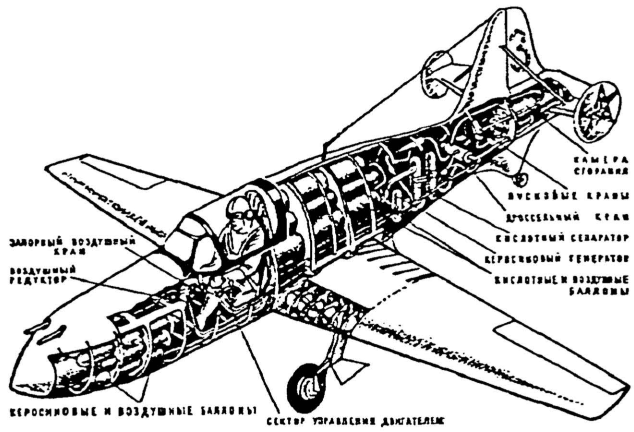
Our Difficulties

But why, then, did we lag behind the Nazis in jet aviation and large rockets?, you may ask. I am sure that the historian will find this question exceedingly interesting; but there is no simple answer. We can, however, recall one or two major facts which, no doubt, contributed to our failure. I think that the (now officially acknowledged) political arrests and murders of the 1935–40 period, known as *Ezhovschina* (Ezhovism, after Ezhov, then the NKVD chief) caused much greater damage than is realized abroad. Far too many scientists, technologists and managers were destroyed, humiliated or disheartened. And rocket experts were no exception. Then, as I have already said, Marshal Tukhachevsky was the top governmental spiritual leader of military rocketry. But, thanks to Nazi provocation, he was shot in 1937 as a "German spy," and this sparked off a whole chain of disasters. Almost all who worked on a project discussed with and authorized by him, or who were in contact with him—as all leading rocket specialists were—had now to face the danger of being proclaimed an "accomplice of a spy."

But even that was not all. The laboratories, production lines, materials, scientists, technologists, inventions and research reports of occupied Norway, Denmark, Holland, Belgium, France, Yugoslavia, Hungary, Czechoslovakia, Roumania, Bulgaria, Poland and now of the European territories of the U.S.S.R., were at the disposal of the Nazis. And what about us? For reasons which can be found elsewhere,* our armed forces were steam-rollered by Hitler's Panzer armies. They swarmed so rapidly towards the notorious "Barbarossa Line" (Volga-Arkhangelsk) that we had to dismantle the remnants of our economy and move them to Siberia—back to square one. The enemy was gaining every imaginable advantage, while we were losing all the normal conditions of work.

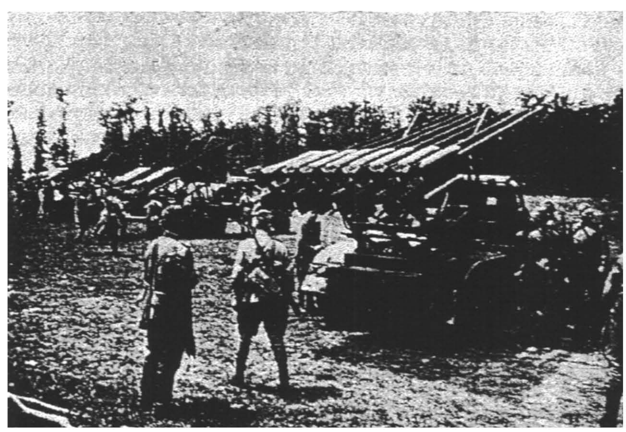
In spite of all this, we survived, and in due course the U.S.S.R. gave the world Sputnik 1, Yuri Gagarin, and many other things. "We are still desperately short of almost everything," I said in a lecture to German scientists and engineers in Leipzig in 1946. "But the fact that we survived an initial defeat; that we preserved our traditions under so many humiliations; that we not only restored our industry under most difficult conditions, but managed to reach a mass-production level in our aircraft, tank, artillery and rocket industries, shows that the Union of Soviet Socialist Republics should not have been looked at by your leaders so superficially . . . I hope that you and your children will be more careful in future. For the U.S.S.R. is not a 'geographical nation,' as Adolf Hitler once said, but a vast land of talented men and women."

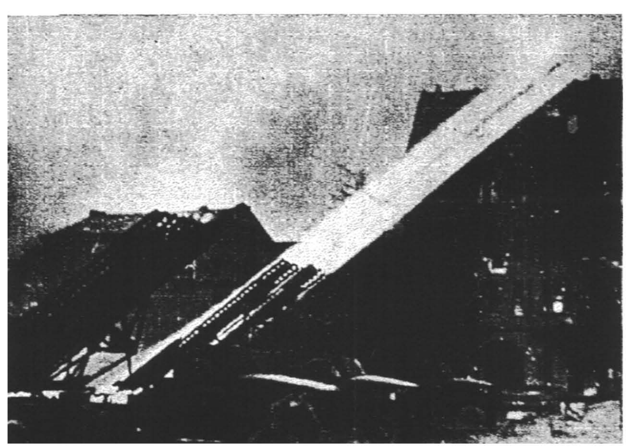
Indeed, from 1942 onwards, the Soviet industry produced about 30 000 tanks and other armoured vehicles, 40 000 aircraft, 120 000 artillery guns (including "Katyusha"), 100 000 mine-throwers, etc. We also learnt—the hard way—the bitter lesson that no self-respecting country can afford to be indifferent to the scientific-technological aspects of national defence; that it is not enough to have a talented people—it must be given a chance to make good use of its ability; also that we had to know our enemy not just as "the Nazi" or "the German," but also as a scientist and technologist.



Above, the first Soviet rocket-fighter BI-1 designed by V. F. Bolkhovitinov which flew in 1942. It subsequently crashed during a low-level speed trial.

Below, Soviet Katyusha rockets used in the defence of Stalingrad pioneered a new era in tactical weapons. Photographs show the method of launching from Army trucks including a "salvo launch" in the assault on Berlin in April 1945.





---

* *"Istoriya Velikoi Otechestvennoi Voiny Sovetskogo Soyuza" (The History of the Great Fatherland War of the Soviet Union), in six volumes, Moscow, 1963, volumes* 1 *and* 2.

Then at last the Soviet government gave its full blessing to all who could contribute to the theory and technology of aviation and cosmonautics. The old GDL, RNII, CAGI, even individuals, began working on rockets of various kinds and types on a much greater scale than at any time before. And I should like to say that by about the end of 1944 we had not only restored the 1941 level, but had also taken a number of steps beyond it, and produced quite a few interesting ground-to-ground and air-to-ground rockets.

A very important, if not historic, role was played here by an organization almost unknown outside (and little known even inside) the U.S.S.R.; this is the BNT-MAP, Byuro Novoi Tekhniki Ministerstva Aviatsionnoi Pomyshlennosti (Bureau of New Technology of the Ministry of Aircraft Production). Here, at 16 Ulitsa Radio, Moscow, in the so-called Old CAGI, under Eng. Col. S. A. Shumovsky, we had a first-class governmental centre of study of national and international aerospace information accumulated via open and secret channels. All the aircraft, rocket, radio, electronic, and other ideas, including theories and projects, were processed and issued, in print or otherwise, as "Express-Information" bulletins, and distributed among the experts concerned. BNT had its own scientific and technical staff, laboratories, large exhibition hall, printing facilities, as well as a beautifully equipped cinema.

In a very short period of time, the BNT introduced our designers, scientists and managers into what was going on in Germany, the United Kingdom, United States and many other countries. Scientific and technological information about the German Me-163A, Me-163B, Me-262, Me-410, He-162, He-219, He-280, the Ar-234 series, Jumo-004, BMW-003, HWK-109-509, etc., as well as about some Anglo-American innovations, found its way into the "Express-Information" bulletins, and then reached the desks of Soviet experts speedily and with remarkable accuracy.

You may thus agree that it is nonsense to write *post factum*—as some still do—that when we arrived in Germany in 1945 we did not know what we were looking for or talking about. On the contrary, in addition to BNT and other information, some of us—I, for one—were supplied with printed books (issued by the General Staff) of lists of all the German industrial, research and educational establishments in aviation and rocketry. We knew, on paper at least, of the more or less significant aircraft and rocket scientist, technologist, administrator, laboratory, experimental station, etc. Before my foot touched German soil, I knew nearly as much about Dr. Wernher von Braun and his associates as was needed professionally. In fact, we knew almost everything about the experiments in Germany from Max Valier and his rocket cars and bicycles (1928), Opel's rocket-planes (1928) and Tilling's rockets (1932–33) to V-1 and V-2.

Yet our task in Germany was "to investigate every piece of metal on the whole of Usedom," as the late Marshal V. D. Sokolovsky put it when we arrived in Berlin-Karlshorst. For we wanted to establish beyond a shadow of doubt why—in spite of our GDL, RNII, GIRD-s, CAGI, Zhukovsky Academy, MAI, CIAM and other establishments, and unquestionably talented aircraft-rocket theoreticians and designers—we had fallen behind the Germans in the actual production of large rockets and jet aircraft. By the way, this was one of the questions levelled in 1946 by the "Bulganin Committee" of the Politbureau against Air Chief Marshal A. A. Novikov, then C-in-C of the Soviet Air Forces, Col. General of Aviation A. I. Shakhurin, then Minister of Aircraft Production, and their associates, who were degraded and punished undeservedly.

Destruction of Peenemünde

We had heard, of course, that on 17 August 1943, some 600 British Lancasters, led by Group Captain Searby, bombed Peenemünde for about 100 min; that during the subsequent weeks concentrated efforts were made by the Anglo-American air forces to raze the mysterious place to the ground. But we also heard and knew that work in Peenemünde continued until the Soviet 19th Army approached Usedom. At any rate, the U.S.S.R. suffered so heavily under the Nazi invasion that none of us could even think, for one moment, of remaining indifferent to the centres of its material strength.

When, however, the units of the 19th Soviet army reached Peenemünde, they had to acknowledge a technological defeat: the condition of the place was beyond comprehension. What had survived the British raids had been dismantled, loaded on special vehicles and trains, and taken away—mainly to the Harz Mountains, then to Oberammergau, in the Bavarian Alps, and thence to America. Projects, research materials, test equipment, rockets, unfinished parts, the most valuable means of production, almost all the scientists and engineers, and even furniture, had managed to escape from Usedom. What could not be taken away had been destroyed or damaged.

Was this, perhaps, only my personal impression? No. Two or three days after the fall of Peenemünde, I was visited at the Zhukovsky Academy by a well-known Soviet aircraft designer who suggested that I should fly with his team to Germany to study the latest Nazi jet aircraft. "If you still hope to see Wernher von Braun," he continued, "I can tell you that he has already escaped to the Americans, and has left nothing behind. Peenemünde is no more than a cemetery of ruins. But some aircraft factories are still in a worthwhile state." I thought he was exaggerating. But about a week or so later, I attended a meeting at which the speaker, a governmental official (just back from Germany) gave us a surprisingly accurate list of Peenemünde people who had left for the South-West. "The remnants of Peenemünde are now, however, under strict guard in order to give our scientists the chance to carry out a point-by-point study of what was going on there up to the moment of von Braun's departure," he told us.

Soon after this meeting, I was called to the office of the Chief Engineer of the Soviet Air Forces. One of the Deputy Ministers of Aircraft Production was also present. We talked about the possible potential value to the Americans of Wernher von Braun's group and of the Peenemünde materials, equipment and projects. What a pity—I said—that von Braun has escaped to the Americans: he could have been useful to us, we would have given him a chance to continue his work. The Chief Engineer, however, seemed to be more interested in jet engines and rockets like Wasserfall, Rheintochter and Schmetterling. "Here we are," the General remarked in a gloomy tone, "the flag of our victory flies over Berlin, but the most deadly weapons of the fallen enemy have walked over to the Americans. . . ."

Our subsequent experience proved that this was an exaggeration, *i.e.*, it would, historically, be inaccurate to assert that the U.S.S.R. got hold of nothing of scientific or technological importance. Of course, I knew only a fraction of what actually happened, but even I could make a long list of captured documents, laboratories, projects and weapons of undoubted value to the Soviet programme of rearmament. But I am also fed up with those in the West who insist that we captured "the whole aviation industry of Germany"; that "the riches of Peenemünde and the Harz Mountains" fell into our hands "intact, with thousands of brilliant scientists"; and that "since 1945, the Soviet scientific and technological achievements were due to the captured Germans." For any assertion carried to its extreme becomes a dangerous absurdity.

Again, what were the facts? On page 7 of a book called *USSR*, by John F. Houston (Oliver & Boyd, London, 1956), there is a photograph of myself and my wife walking at the

head of a party of Soviet aerospace scientists and engineers who were sent to Germany by the government of the U.S.S.R. to obtain all the answers. I have not the slightest idea who managed to take this photograph, and how; but let me tell you that this *was* the group authorized to have access to all the relevant facts. To make the point still clearer, it may be useful to add also that immediately after the Potsdam Conference my own office was moved from the Air Force Department of the Soviet Military Administration to Marshals G. K. Zhukov's and V. D. Sokolovsky's "Berlin Kremlin" in Karlshorst, which, you might agree, put me in a good position to know the truth of what was going on. I shall, therefore, allow myself to touch upon some facts which speak for themselves: *amicus Plato, sed magis amica est veritas!*

The German Specialists

When I arrived in Peenemünde, there was hardly a German sufficiently competent to talk about V-2 and other big stuff. There were many, almost all, claiming to be V-2 experts, but none of them was a leading figure. When I asked one of the "V-2 experts" why he had not joined the group headed by Wernher von Braun and Walter Dornberger, which had fled to the Americans, he said that he preferred to render his unique knowledge to more progressive forces, *i.e.*, to the Soviet Union. "But how would you define your 'unique knowledge'?" I asked. "What exactly were you doing in Peenemünde?" He talked and talked and talked, and displayed the typical characteristics of a typical secondrater. Our people then brought another two men to me, whom they described as outstanding engineers. I spent two whole days with them, but the conclusion was the same: they knew their branches of the tree, but were not experts on the tree as a whole. All the othen men proved to be of a similar or even inferior calibre. Thus, not only in Peenemünde, but also in all Soviet-occupied Germany, we found not a single leading (*sic*) V-2 expert.

But we were not prepared to give up. With the voluntary or involuntary help of hundreds of ordinary German scientists, engineers and workers, we attempted to restore the technological process of production and operation of the V-2, *i.e.*, not the actual production but its technological sequence and techniques. I remember saying to Dr. Brunolf Baade in Dessau in 1945: We won the war and lost the V-2, but we are going to win the jet-rocket race quite independently of you, the Germans. "I wish you success. But how?" he asked. I said I would tell him how: "We will try to marry our own theories and projects with your production experience, and that, I think, will be good enough."

On the eve of the Potsdam Conference, in a report to Marshal of the Soviet Union G. K. Zhukov, I repeated the same idea with equal force. I wrote: "We failed to get hold of the leading experts, projects and research materials of the V-2: they are all either already in America, or on their way there. No doubt, this will give the Americans important advantages. But there is no scientific/technological ground for undue worry, because, first, we know precisely whom and what the Americans have acquired; second, we know what von Braun and his men were working on by the end of the war; third, we shall be able to re-establish the production sequence of the V-2; and, fourth, we have our own theories and projects, and von Braun's, which are quite good."

Needless to say, not everyone agreed with this point of view. For instance, General Vassily Stalin (Marshal Stalin's son) thought, at the time, that I over-estimated our scientific potential. But, indeed, the study of the German archives and materials made some of our doubts crystal-clear. First of all, we were horrified to discover that important Soviet secret research results, projects and institutions were known at Prinz-Albrechtstrasse. Secondly, which made a positive impact upon us, comparisons showed that, so far as theories and projects were concerned, the Soviet rocket scientists and engineers appeared to be, basically, as advanced, as inventive and as clever as their German counterparts; but in putting these theories into practical technology we turned out to be miles behind the Germans.

In this connection, I should like to quote an extract from my introduction to a bulky report on "The State of Aviation and Rocketry in Germany," prepared by the Air Force Department of the Soviet Military Administration in Berlin-Karlshorst:

"*Point-by-point comparisons disprove the somewhat rooted opinion that we are, scientifically and technologically, inferior to the Germans, French, British and Americans. The material collected and analysed in this volume shows that M. K. Tikhonravov's rocket No.* 09 *was launched long before V-*2 *appeared on paper; that L. S. Dushkin's engine ORM-*65 *was designed, built and test-fired before anybody knew about the German HWK-*109-509; *that our BI-*1 *was designed, constructed and flight-tested before the German Me-*163*B. . . . But the historic fact is that they, the Germans, produced thousands of V-*2*s and many Me-*163*Bs, while we failed to have operational rockets of the V-*2 *calibre and rocket fighters.*"

In an address given at a closed meeting of the staffs of the Military and Air Force departments of the Soviet Military Administration in Germany, in December 1946 (to quote from my diaries), I stressed these points once again, perhaps somewhat more vigorously:

"*As we all know, immediately after the Potsdam Conference we gave to our Western Allies sectors in Berlin. They, in turn, allowed us to extend our zone of occupation to its present boundaries. Of course, the Americans and British first removed all they considered valuable to them. Trains loaded with aircraft, rocket and other equipment were leaving for the British and American zones from Dessau, Bleicherode, Nordhausen, Magdeburg, Jena and other places just before we arrived. Nevertheless, here we were more fortunate than in Peenemünde. Somewhere, somehow, our men have managed to get hold of interesting objects, including several complete V-*2 *rockets. They have found very interesting scientific papers. And, of course, the remnants of the Jumo factory in Dessau will prove to be extremely valuable to our aviation. But again, not a single significant rocket specialist! There is, however, no ground for pessimism. What we really need is practical experience; and there are in our zone at least hundreds of ordinary technicians and workers, who will help us in one way or another. As to the loss of Dr. Wernher von Braun and his men, let me tell you that it will soon be adequately compensated by our own designers and theoreticians.*"

The question was, how and where were we to go from what we found, or failed to find, in 1945–46? Once again, I should like to answer by quoting from my own earlier report to the C.-in-C. of the Soviet Air Forces:

". . . *The problem we face today is this: we have no leading V-*2 *experts in our zone; we have no complete projects or materials of the V-*2*; we have captured no fully operational V-*2*s which could be launched right away. But we have lots of bits and pieces of information and projects which may be very useful to us. We have the free or compelled co-operation of hundreds of German workers, technicians and second-rate scientists, whose experience could be of value to us. In the circumstances, I think the best thing to do is to organize all these into a group, in Peenemünde, to give it a set task, and to find out what it can do for us here in Germany.*"

May I say that this opinion was shared by many people, both in Moscow and Berlin. Major-General of Aviation A. G. Kostikov, the creator of "Katyusha"; Major of Engineering Service P. Pronin; Professors V. S. Kulebakin, K. L. Bayev, D. A. Ventzel, B. S. Stechkin, S. A. Khristianovich

and B. N. Your'ev, whose advice I always enjoyed and valued, were in no doubt at all that we were in danger of being obsessed by the hysterical formula "German Specialists." Professor G. F. Burago and Engineer I. A. Merkulov, who visited me in Berlin separately and hardly knew each other, reacted with one and the same question: what can the men in question add to what we already know? And S. P. Korolyev remarked that "we must have a little more self-respect."

But the leaders preferred to listen to Marshal L. P. Beria and Colonel General I. A. Serov, the security chiefs of the U.S.S.R., who, in turn, preferred to listen to men like Major General of Aviation (as he still was) Vassilii Stalin and Major General of Aviation G. A. Aleksandrov. I remember distinctly reporting to Colonel General P. A. Kurochkin, then Deputy C.-in-C. of the Soviet Military Administration, in the presence of Lt. Generals Dratvin and Kutzevalov, that taking the "German specialists" en masse to the U.S.S.R. may well prove to be a soap bubble, because "the absolute majority of them associate themselves with von Braun's glory, which is now in America."

German Rocket Collective in Russia

So, in October 1946, very many "specialists" and their families were loaded on to trains and taken to the U.S.S.R. I do not know how many of them were real specialists, or how many rocket engineers. They arrived in the Mytischi-Tchkalovskaya-Monino region, north-east of Moscow. This was, perhaps, one of the most careless aspects of the whole affair. For, indeed, was it wise to unload a large party of ex-enemies, at any rate of foreigners, in a region of concentration of the most secret state defence (air force) establishments? And when this was realized, someone, somewhere, pushed the pendulum to its opposite position, which predetermined the fate of the group: it was taken to Gorodomlya, a wildish little island in the middle of Lake Seliger, west of Kalinin, near Ostashkov.

This was the perfect spot for complete isolation. Also, the Seliger-Il'men area was one of the bloodiest during the Soviet-Nazi war, especially in January 1942, and the word "Nemets" ("the German") had become one of the most hated words.

Here the group worked under the general supervision of a well-known Soviet rocket engineer, Yu. A. Pobedonostsev—the only link between the Soviet rocket groups and the Germans. Their major task was to work on improvement of the V-2s performance. But about one year later it became apparent that (1) the Gorodomlya version of V-2, called Project R-10, could not, even if completed, meet the essential strategic requirements; and (2) a group of Soviet rocket engineers developed, built and test-fired (somewhere else, independently) a project known as "Pobeda" or R-14. This was, really, an improved version of V-2. Its performance surpassed the characteristics of R-10 (still on paper), and as a result the Gorodomlya group "suddenly" became redundant. For a time it was allowed to continue its work, but gradually it was asked, via Pobedonostsev, more and more to do specific jobs dictated by the needs of the Soviet rocket groups. The months of the Gorodomlya group were numbered.

The success of R-14 brought also other consequences. It was recognized that neither the original V-2 nor the R-14 lived up to the requirements of the new rocket era.

Towards the ICBM

"This V-2 is not what we want," G. M. Malenkov, then still Stalin's No. 2, said to us in 1947. "We have improved it, we have more than reached the Peenemünde level of 1945, but, even so, it remains a blind, short-range, primitive weapon. Who, do you think, can we frighten with it? Poland? Turkey? But we are not going to frighten Poland. Our potential enemy is thousands of kilometres away. We must work on the development of long-range rockets. The importance of Saenger's project must be seen in the fact that it can fly very long distances. And we certainly cannot wait until the American imperialists add Saenger's rocket-plane* to their B-29 and Atom Bomb."

I asked a leading Soviet rocket designer, A. G. Kostikov, what he thought of this rather categoric statement. He replied, smilingly, that Malenkov was right in 1944, in 1945 and 1946, and is right today. "As for you and me," he continued, "we know what to do: avoid putting our trust in the Gorodomlya and Nikol'-skoye† Germans, and push ahead with our job. They all seem to be chained to the idea and scale of their old V-1 and V-2."

This was, perhaps, a little unfair. After all, the German R-10 project contained some new and useful ideas; they had tried hard and there were bright minds among them.

Incidentally, it was during the same conversation with Kostikov that the problem of putting a Sputnik around the Earth emerged, for the first time (for me, at least) as a practical technological proposition. The immediate reason was that the solution of the problem of long-range (inter-continental) payload delivery—the main problem of strategic rocket design—led inevitably to the problem of flight beyond the atmosphere and, consequently, the effective gravitational field.

Sputnik and the Saenger Project

V. F. Bolkhovitinov came to me at home in Moscow. We first discussed the merits and shortcomings of Saenger's project; for him this was no more than an enlarged version of his BI-1, and I agreed with that. At any rate, said Bolkhovitinov, why not put something like BI-1 on top of a multistage rocket, as its last stage, and release it at a certain altitude, so that it could continue a controlled flight and then return to the Earth? "This, I think, offers a reasonable solution to the problem of recovery of the payload-carrying stage of a heavy rocket. Besides, should man ever succeed in putting a satellite round the Earth, he will have to find a method for bringing it down, and here again wings may prove to be good."

In 1947, at the Zhukovsky Academy, I had interesting discussions with a group of eminent figures in jet propulsion, aerodynamics, ballistics and mathematics, and they responded to the Sputnik idea with basic optimism. A day or two later, I saw Academician S. A. Khristianovitch, the "King of Gasdynamics" in the New CAGI, a man whose contributions to the emergence of supersonic aviation and rockets in the U.S.S.R. cannot be over-estimated. "Yes, yes, of course," he said, "Sputnik is a possibility, an interesting proposition, a very much needed 'thing'." He then outlined the basic gasdynamic problems involved.

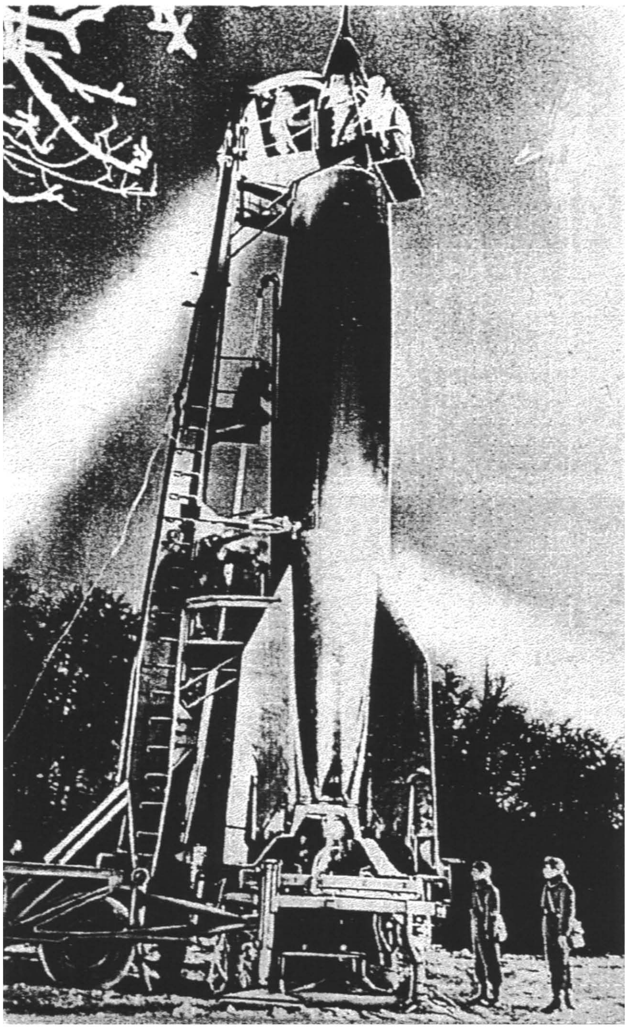
Unfortunately, however, some less competent but more powerful men reacted differently. Major General of Aviation Vassilli I. Stalin—"the Big Boy"—allowed himself even to shout at me: "others may be wasting their time on abstract projects, but you are a service man, and you must be concerned with the practical needs of state defence. Can't you understand that we need jet-fighters, not a silly Sputnik?!"

Lt. General of Aviation T. F. Kutzevalov, Hero of the Soviet Union, Head of the Air Force Department in Berlin-Karlshorst, when I presented the first draft of the TT-1

---

* *A detailed proposal for an "antipodal bomber," launched by a captive booster from a railed track, and capable of extending its range using the "skip-glide" technique (see "Astronautics in the Sixties" by K. W. Gatland, Iliffe Books Ltd., 1962, pp. 254–258).*

† *This was, really, the Kapustin Yar group, south-east of Stalingrad, the first Soviet post-war "Peenemünde."*



Immediately after World War 2 the U.S.S.R. Ministry of Armaments restored a serial production of the Peenemünde V-2 on Soviet soil under the name "Pobeda" (Victory). The rockets were used mainly to gain experience with launching techniques and to evolve basic concepts for the organization of Rocket Divisions in the Soviet Army.

Novosti Press Agency

multistage rocket, said that American aircraft were violating our air space. "This shows that the danger of a new war is real; therefore there is no time for abstract Sputniks."

And what about the ruling Olympus itself?

On 14 March there was a meeting in the Kremlin. Present were: G. M. Malenkov; N. A. Voznesensky; Air Marshal K. A. Vershinin; Minister of Armaments D. F. Ustinov; Deputy Minister of Aircraft Production Lukin; aircraft designer A. S. Yakovlev; aircraft designer A. I. Mikoyan; T. F. Kutzevalov, and myself. I was sitting next to Malenkov, who asked me in a whisper whether any progress had been made "on the matter," *i.e.*, on the Sputnik idea. "Yes, but not very much," I whispered back. "Go on trying," he said, "and let me know as soon as there is something worth knowing." When the meeting was over, someone half jokingly remarked that he knew of my "new interest." But did I really believe that "the thing" was a practical proposition? I replied, also in a joking manner, that one day he would see a Sputnik above his head and beyond the range of our MiGs. Marshal Vershinin interrupted that, yes, he, too, believed in the Sputnik idea.

I was called back to N. A. Voznesensky's office. The Deputy Prime Minister said that he would be reporting to Comrade I. V. Stalin, therefore he would like to clarify one or two technical points. "First," he asked, "have you, personally, checked Saenger's calculations?" (I had.) "Second, do we have enough sufficiently experienced experts to embark on a project of this magnitude?" (I named the leading experts.) "Third, could some of the Germans in the U.S.S.R. be invited to participate in the work?" (No, I did not know any among them.) "Fourth, if we embarked on this project, what would happen to the Sputnik idea?" (I should work in both fields, I replied, and Voznesensky approved this.)

Some 24 hr later, I was at a meeting of the Politbureau Council of Ministers, in Stalin's office. Present were: I. V. Stalin, V. M. Molotov, K. E. Voroshilov, A. A. Zhdanov, A. I. Mikoyan, L. P. Beria, G. M. Malenkov, N. A. Voznesensky, Col. General I. A. Serov, and myself as speaker. The topic was Saenger's project and rockets. I cannot, of course, disclose everything discussed and decided at this meeting. Nor can I be held responsible for the vulgarizations, exaggerations and rumours about it ascribed to my name in books and articles all over the world. But let me say that I loved my country no less than members of the Politbureau, and, in my humble capacity, worked for it to the best of my ability. Accordingly, I did carry out the decisions so far as was possible: there was no shadow of sabotage on my part.

Indeed, as a scientist, I was interested in scientific exploration and technological improvement. I was convinced that no country in the developed world needed this more acutely. Neither was there any shadow of doubt in my mind that we needed national *defence*—as opposed to *offence*—and peace; because, first, every nation has the right to self-defence,

Detailed investigations of Nazi arms achievements were made in Germany by top Soviet specialists. In this photograph taken during a hunting trip near Schwern in 1946 are, left to right, Lt-General of Aviation Kutsevalov, head of the Air Force Department; Eng-Colonel Tokaev-Tokaty, Chief Rocket Scientist; and Colonel-General Klokov, Deputy C-in-C of the Air Forces of the U.S.S.R.

G. A. Tokaty (private collection)

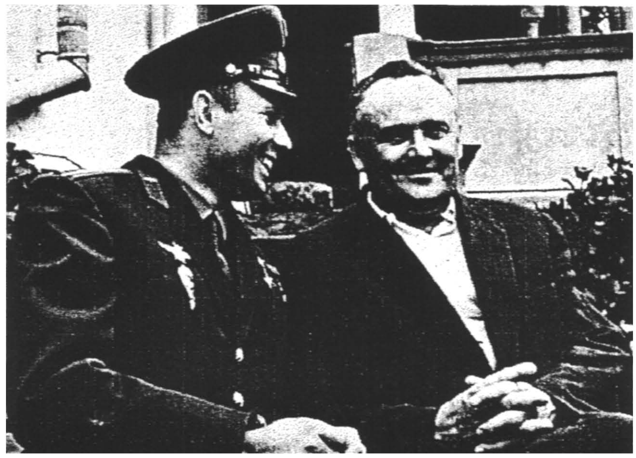
second, the war had transformed the European part of the U.S.S.R. into a huge cemetery of ruins, and we had to re-cultivate it. But when an almighty ruler, twists one's thoughts about space exploration and national defence towards inter-continental bombers capable of reaching New York and Los Angeles, Washington and Chicago, one has to think also about the other chaps' intercontinental monsters capable of reaching one's own Moscow and Sverdlovsk, Kiev and Baku. When you talk about Sputniks and he reacts by talking in terms of putting the president of a mighty world power in a strait-jacket, and calls him "that noisy little shop-keeper," you have to pinch yourself to find out whether it is a nasty dream or a reality.

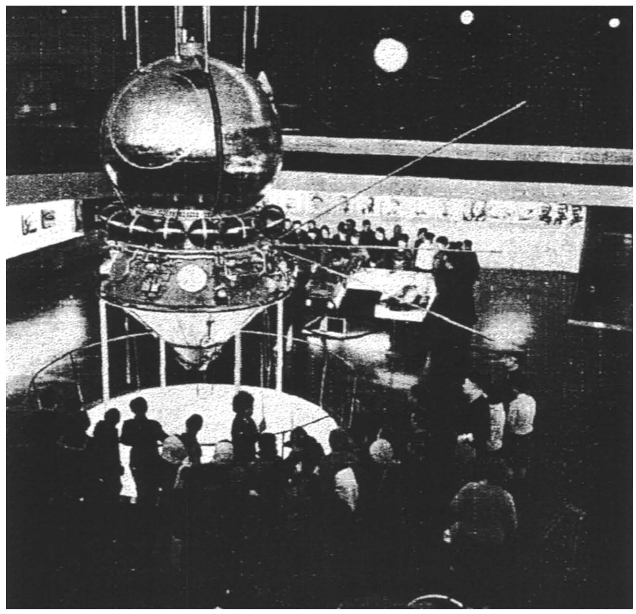
The meeting decreed the formation of a special committee on the Saenger Project: Colonel-General I. A. Serov, 1st Deputy Minister of the Interior; Lt. Colonel Doc. G. A. Tokaev (Tokaty), the Soviet Air Forces; Professor V. M. Keldysh,* Ministry of Armaments; Professor S. T. Kishkin,† Ministry of Aircraft Production; and Major-General of Aviation V. I. Stalin. For reasons unknown to me, my suggestion to have Major-General of Aviation V. F. Bolkhovitinov instead of Serov and M. K. Tikhonravov instead of Keldysh was rejected. I was not happy either with the addition of V. I. Stalin. What made me still more unhappy, however—in fact, very angry—was V. I. Stalin's arbitrary decision (he just dictated a minute without even asking anyone at the meeting) to resort again to the so-called "German specialists."

As it transpired, the work of the powerful committee was doomed to failure. In the meantime, in Berlin, we continued to work on the TT-1 multistage rocket, with and without Sputnik. By about mid-October 1947, the summary of the work, with appropriate sketchy drawings, was sent to G. M. Malenkov and M. Khrunitchev (Minister of Aircraft Production).

But here I should like to stress that the project in question was neither the first nor the only project of the kind. Indeed, I knew that the problem had been under active theoretical discussion for some time, certainly before my proposals, and that "Sputnik work" was already going on elsewhere, though still without formal—written—governmental authorization. It was one of the other groups which produced, in due course, Sputnik-1. As to the fate of our work, I am sorry to say that it constitutes another story, which will have to wait until a more appropriate time.

Just one final point. More than once I have been asked whether it is true that Tsiolkovsky and Tsander were "lonely men ignored by the Soviet government." No, it is not true! During the 1925–35 period, the State publishing houses and journals of the U.S.S.R. published fifty-eight books and articles by Tsiolkovsky; in 1919 he was elected to membership of the Academy of Sciences; all his work was financed by the State; during 1929–34 he consulted the major rocket and airship research and development organizations; and, almost invariably, he was invited either as an active participant or as a guest of honour to important conferences and symposia in his field. Besides, he was a close friend of I. T. Kleimenov, the Head of the Reaktivnyi Nauchno-Issledovatel'kii Institut (Scientific Research Institute of Jet Propulsion of the Ministry of Armaments), and thus knew about the aims, intentions and technological achievements of the State right up to the year of his death (1935).





In April 1961 Academician S. P. Korolyev—the "unknown" Chief Constructor of Spaceships—saw the dreams of Tsiolkovsky, Tsander, himself and others come true in the first manned orbital flight achieved by cosmonaut Yuri Gagarin. Photographs show Gagarin and Korolyev after the historic flight; and below a full-size replica of the Vostok spacecraft at the K. E. Tsiolkovsky State Museum in Kaluga.

Novosti Press Agency

With regard to Tsander, he was a member of CAGI—the central governmental research and development establishment in aeronautics—had access to the State Committees of Armaments and Aviation, occasionally lectured at the Zhukovsky Academy and Moscow Aviation Institute, had a number of meetings with Marshal Tukhatchevsky and C.-in-C. of the Soviet Air Forces Ya. I. Alksnis, was entrusted to lead the first Soviet rocket engine design team, and the State paid all his research and development expenses.

Acknowledgements

The author wishes to express his thanks to Dr. A. R. S. Bramwell and Miss A. Starnes for assistance in preparing the manuscript.

* *Vsevolod Mstislavovich Keldysh is now the President of the Academy of Sciences of the U.S.S.R. Mathematics and aerodynamics are his fields of professional interest.*

† *Sergei Timofeyevich Kishkin is now a full member of the Academy of Sciences of the U.S.S.R. Since the early thirties, he has been one of the most eminent experts in the field of materials (armour).*